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Title:	The TRANSIMS Framework
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Los Alamos
NATIONAL LABORATORY

Form 836 (10/96)

The TRANSIMS Framework

B. W. Bush and the TRANSIMS team
Los Alamos National Laboratory
28 June 1999

Abstract

TRANSIMS (Transportation Analysis and Simulation System) is an integrated system of travel forecasting models designed to give transportation planners accurate, complete information on traffic impacts, congestion, and pollution. The underlying TRANSIMS philosophy is that individual behaviors and their interactions, as constrained by the transportation system, generate the transportation system's performance. To effect that performance in a simulation, individual behavior must be modeled. This presentation outlines the framework of software modules that constitute TRANSIMS, providing details on their purpose, input and output data, and algorithms; it also explains how the TRANSIMS Selector holds the framework together.

Los Alamos National Laboratory is leading this effort to develop these new transportation and air quality forecasting procedures required by the Clean Air Act, the Intermodal Surface Transportation Efficiency Act, and other regulations; it is part of the Travel Model Improvement Program sponsored by the U.S. Department of Transportation, the Environmental Protection Agency, and the Department of Energy.

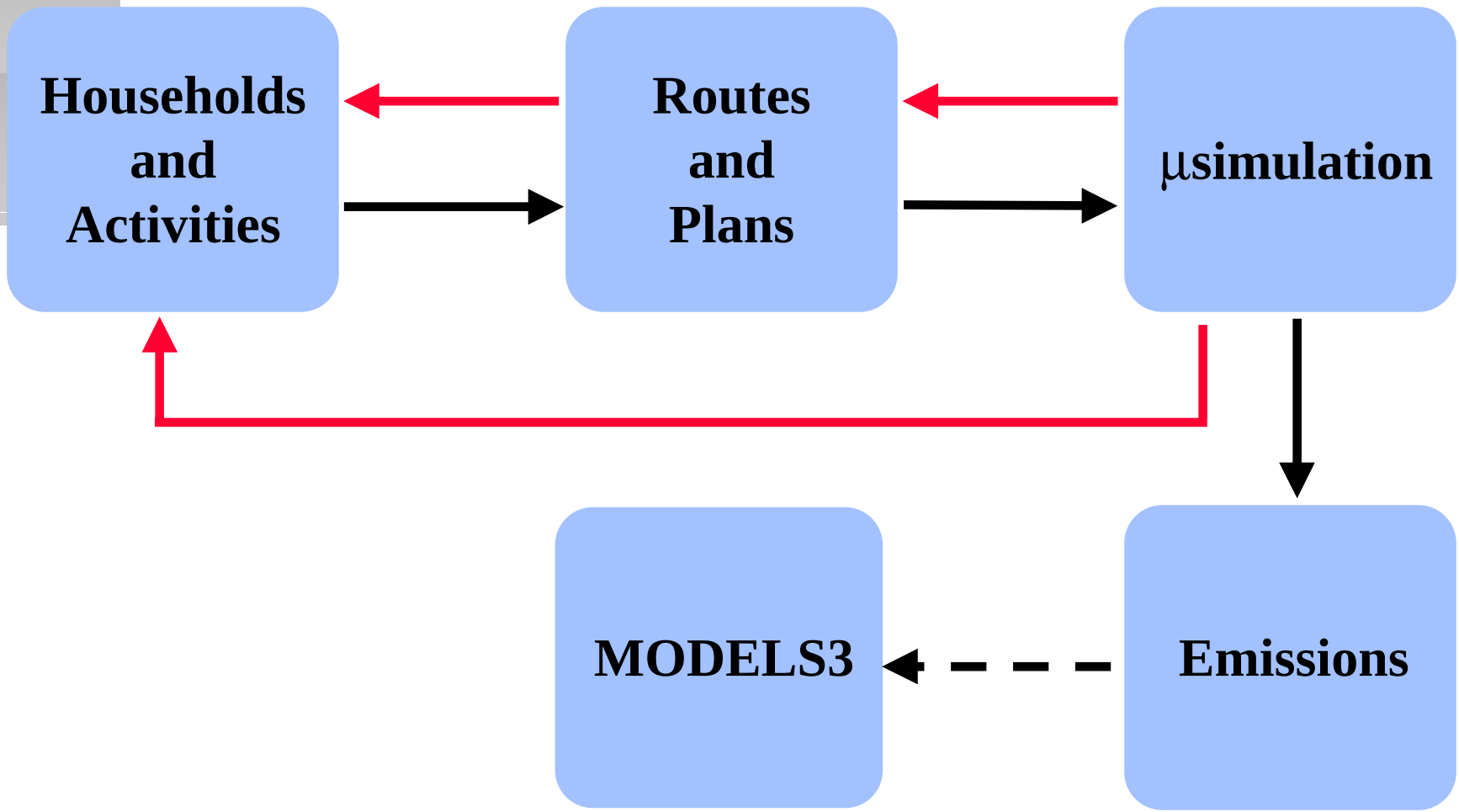
Outline

- *approach*
- *software modules*
  - *population synthesizer*
  - *activity generator*
  - *route planner*
  - *traffic microsimulator*
  - *emissions estimator*
  - *output visualizer*
- *the framework*
- *the “selector”*
- *examples*
- *future directions*
- *conclusion*

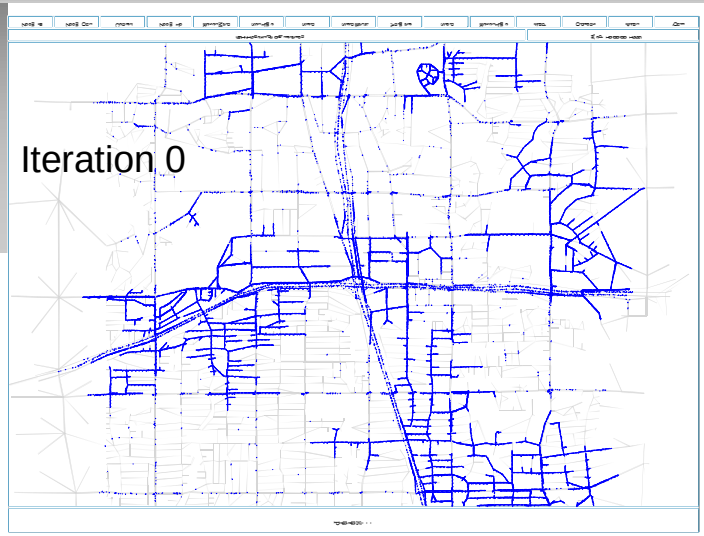
TRANSIMS Approach

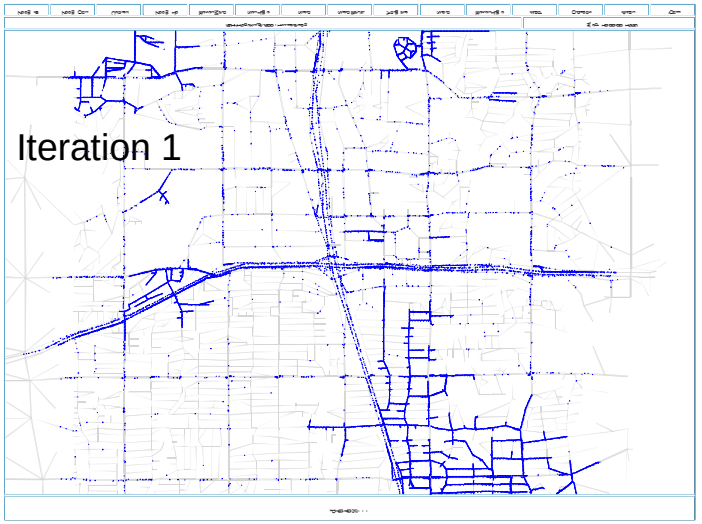
- *virtual metropolitan region created comprising complete representation of a region's . . .*
  - *individuals*
  - *activities*
  - *transportation infrastructure*
- *trips planned to satisfy individuals' activity patterns*
- *movement of individuals across transportation network simulated on a second-by-second basis*
  - *realistic traffic dynamics produced from interactions of individual vehicles*
  - *vehicle pollutant emissions and fuel consumption estimated*
- *models iterated*
  - *stabilizes simulation*
  - *allows travelers to react to information about the satisfaction of their preferences*

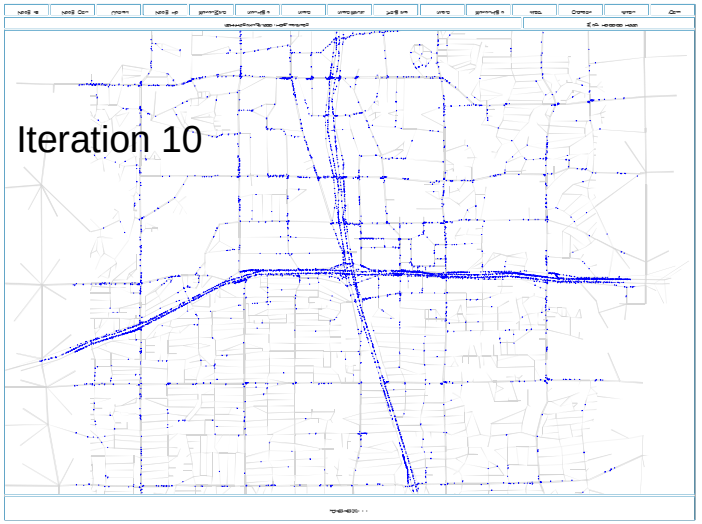
Major TRANSIMS Components



Iteration in TRANSIMS





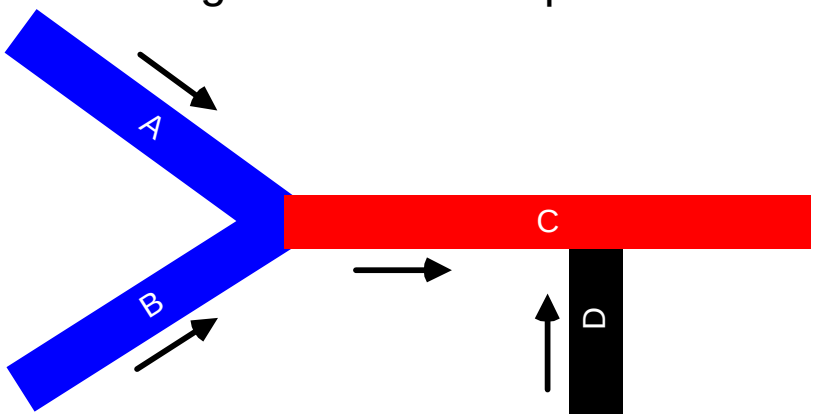


- *feedback is required to stabilize a nonlinear system*
- *the iteration process lets activities, route plans, and traffic converge to quasi-equilibrium*
- *some experiments/studies need to control the flow of information among TRANSIMS components between iterations*

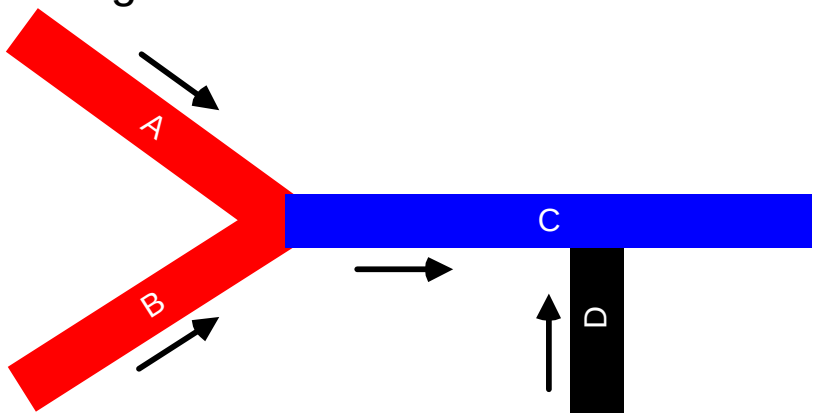
Feedback in TRANSIMS

- *The route planner only "sees" link capacities and travel time delays.*
- *The traffic microsimulation accounts for intersection impedances and other vehicle interactions in addition to link capacities.*
- *Feedback of link travel time delays output from the traffic microsimulation into the route planner is necessary in order to generate realistic traveler plans.*
- *Example: Without microsimulation feedback, the planner would think that link* C *is congested and not route any traffic through link* D *onto link* C*.*

congestion in route planner



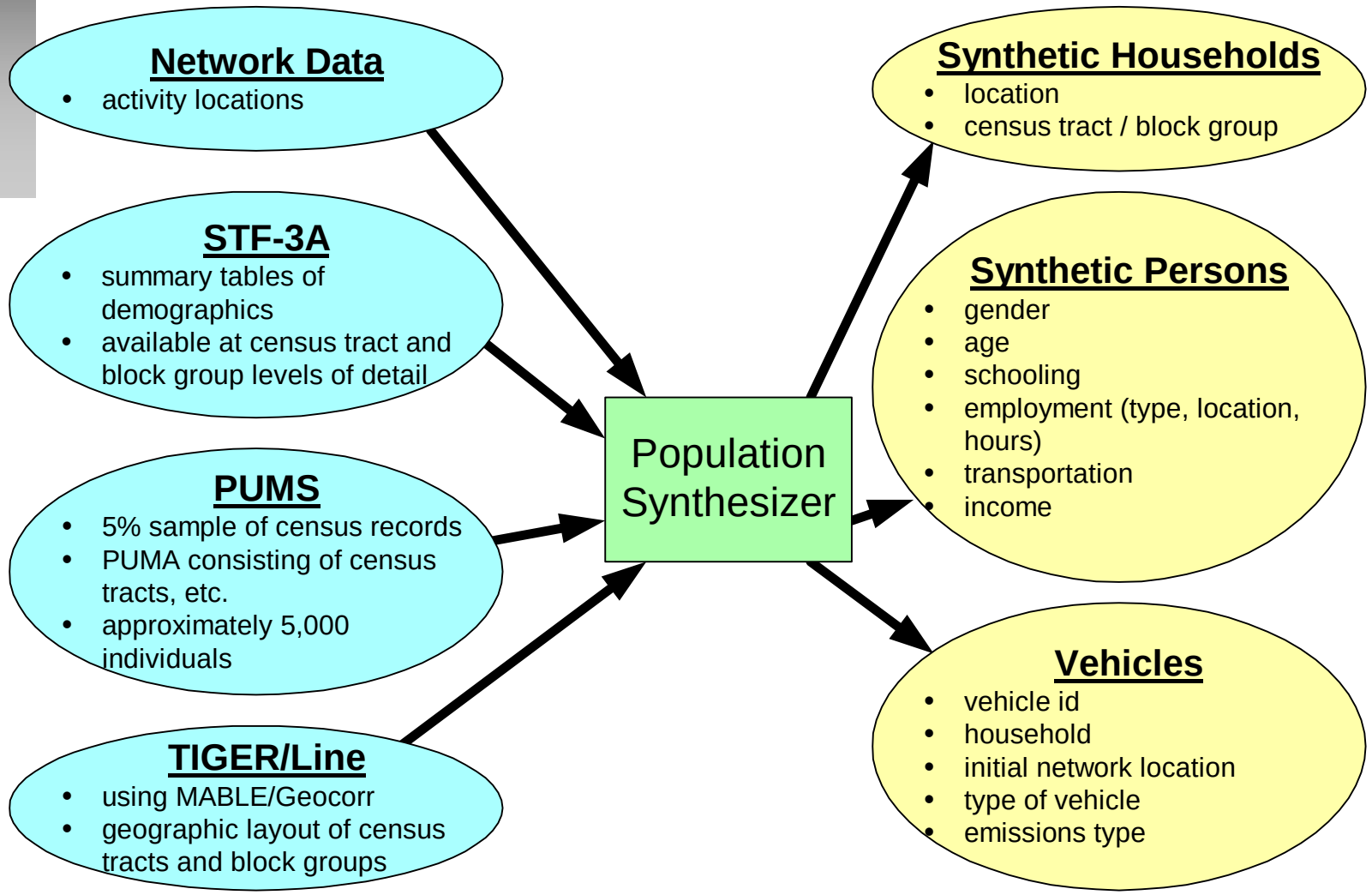
congestion in traffic microsimulation



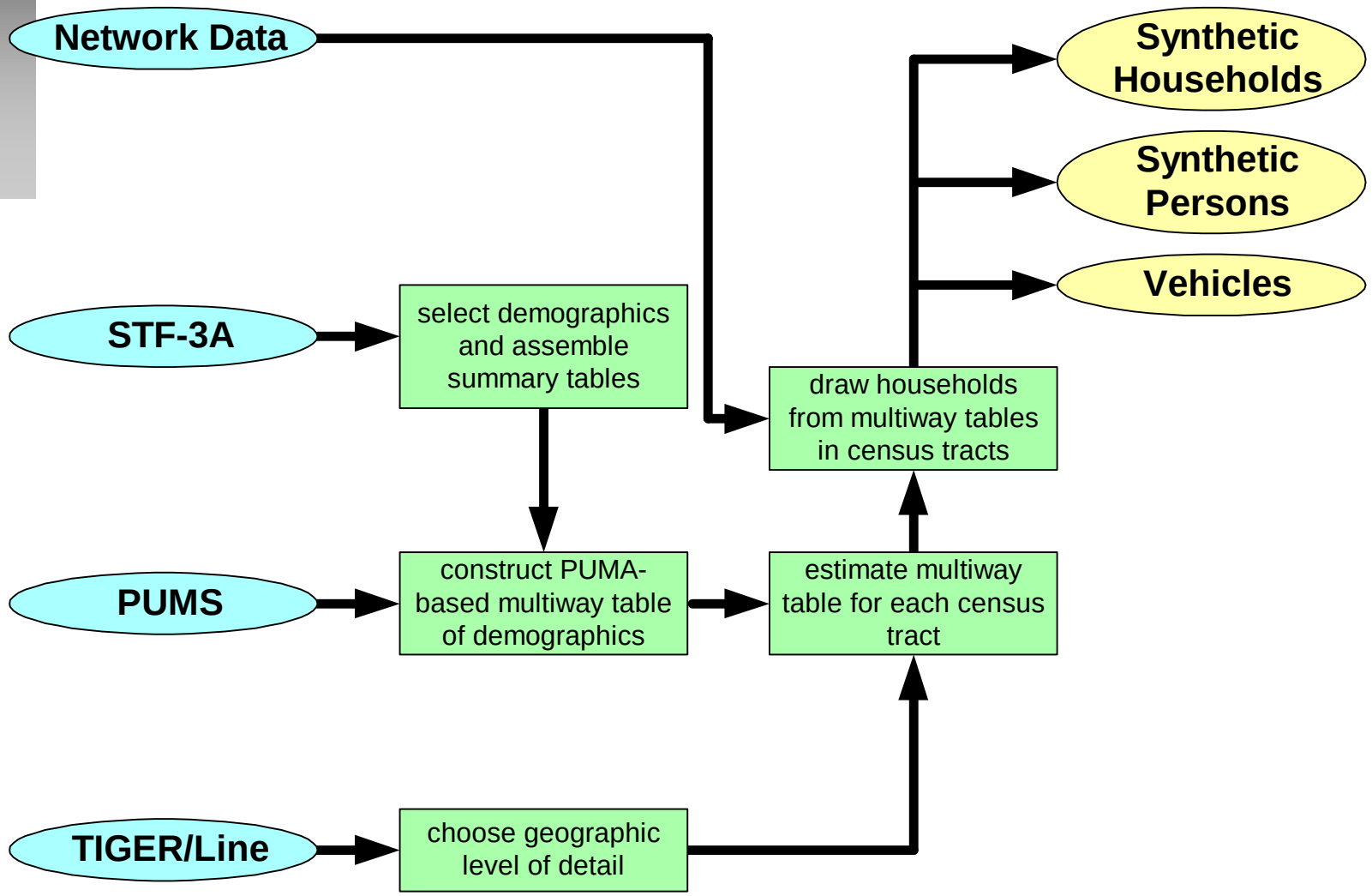
Population Synthesizer: Purpose

- *creates a regional population imitation*
  - *demographics closely match real population*
  - *households are distributed spatially to approximate regional population distribution*
  - *household locations determine some of the travel origins and destinations*
- *synthetic population's demographics form basis for individual and household activities requiring travel*

Population Synthesizer: Data Flow



Population Synthesizer: Algorithm



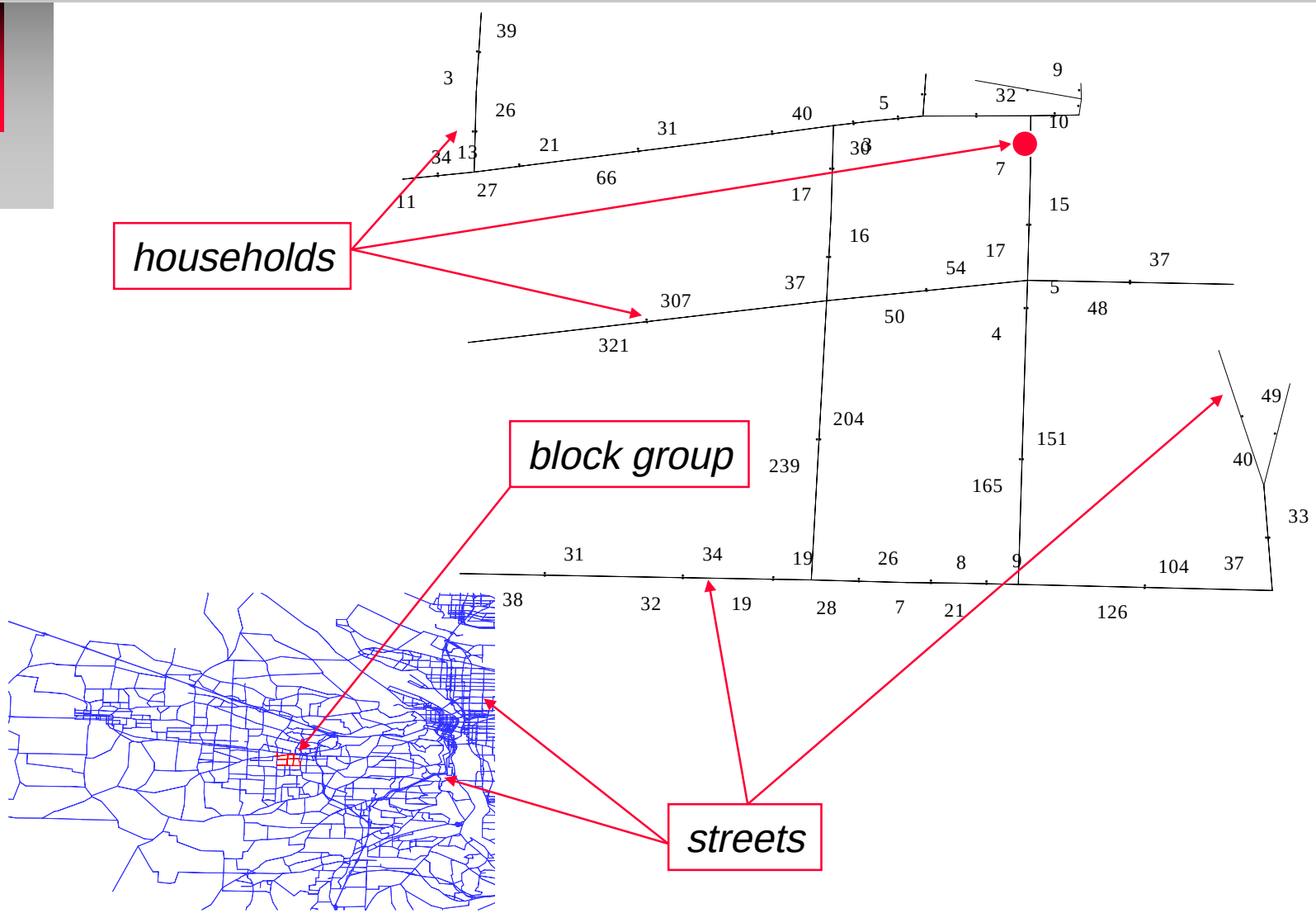
Choice of Variables from STF-3A Summary Tables

- *family households*
  - *age of the householder [P24]*
  - *family income [P107]*
  - *number of workers in the family [P112]*
  - *poverty status × race × family type × presence and age of children [P124A,B]*
- *non-family households*
  - *household type and gender [P17]*
  - *race × household type × presence and age of children [P20]*
  - *age of non-family householder [P24]*
  - *non-family household income [P110]*
  - *poverty status × age of householder × household type [P127]*
- *group quarters*
  - *group quarters [P40]*
  - *group quarters × age [P41]*

Example Household from PUMS in Portland, Oregon

Age	26	26	7
Income	$27k	$16k	$0
Status	worker	worker	student
Automobile			

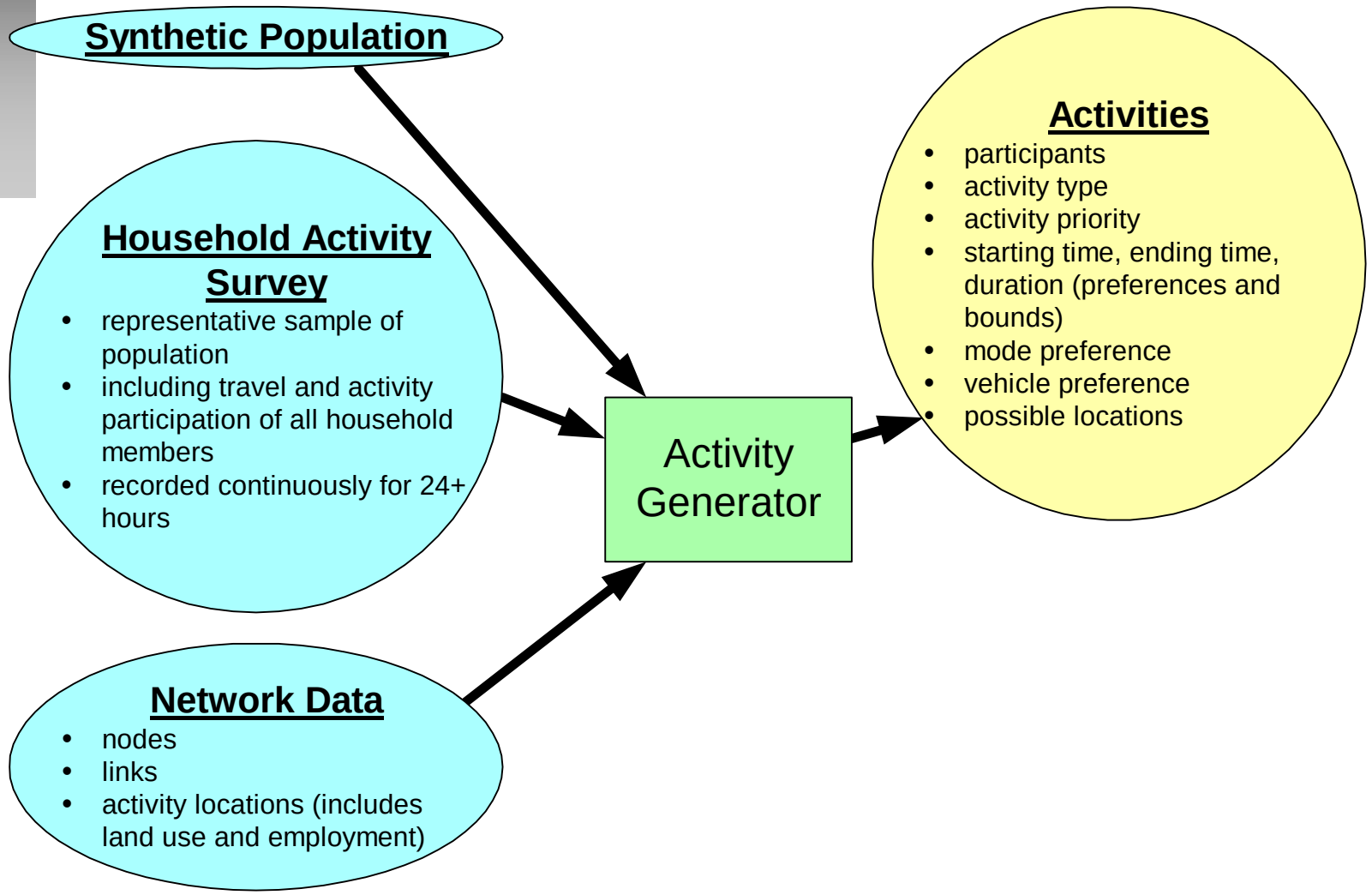
Example Block Group (#312002) in Portland, Oregon



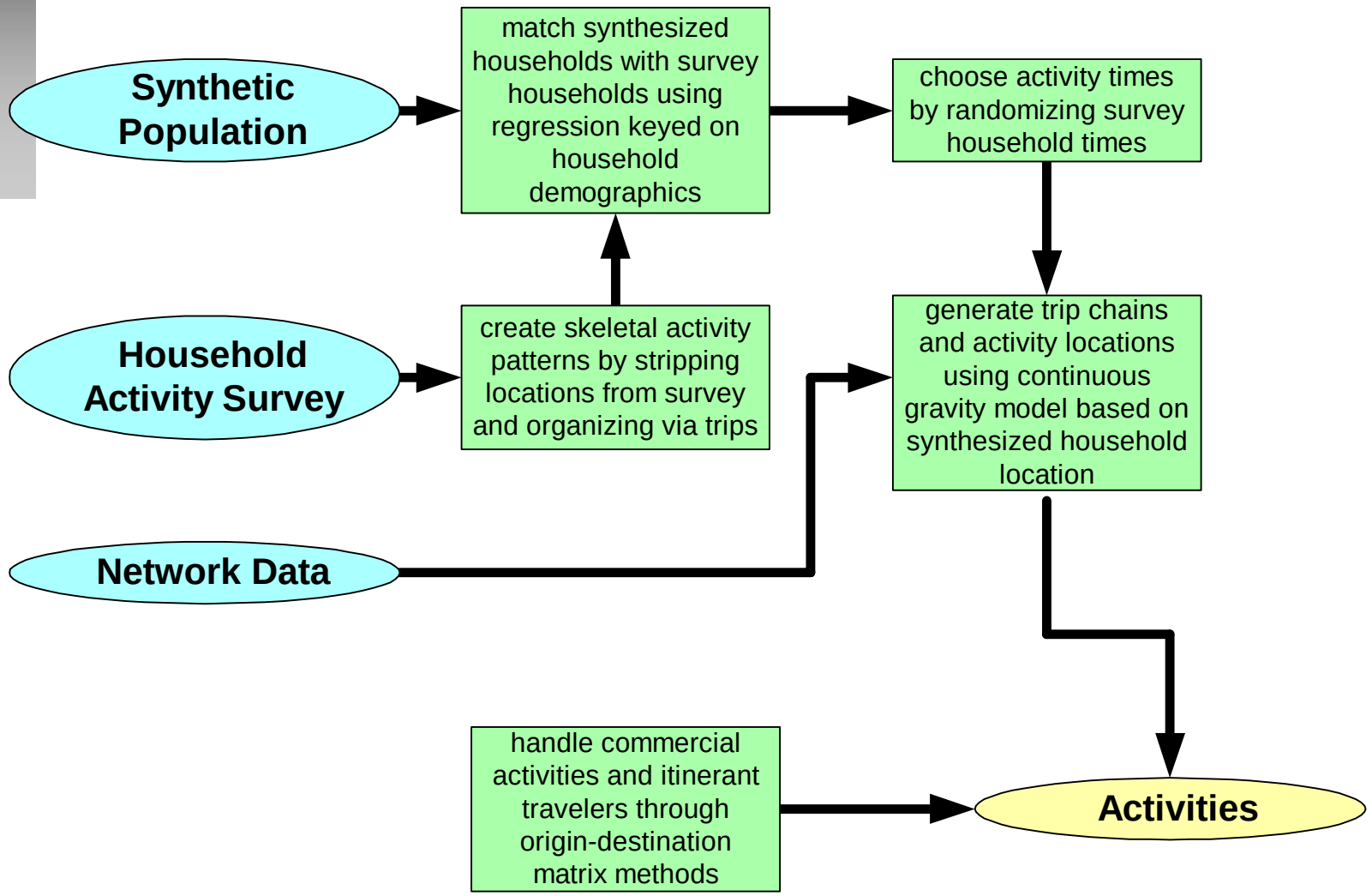
Activity Generator: Purpose

- *creates . . .*
  - *household and individual activities*
  - *activity priorities*
  - *activity locations*
  - *activity times*
  - *mode and travel preferences*
- *generates travel demand sensitive to demographics of synthetic population*
- *activities form basis for determining individuals' trip plans for the region*

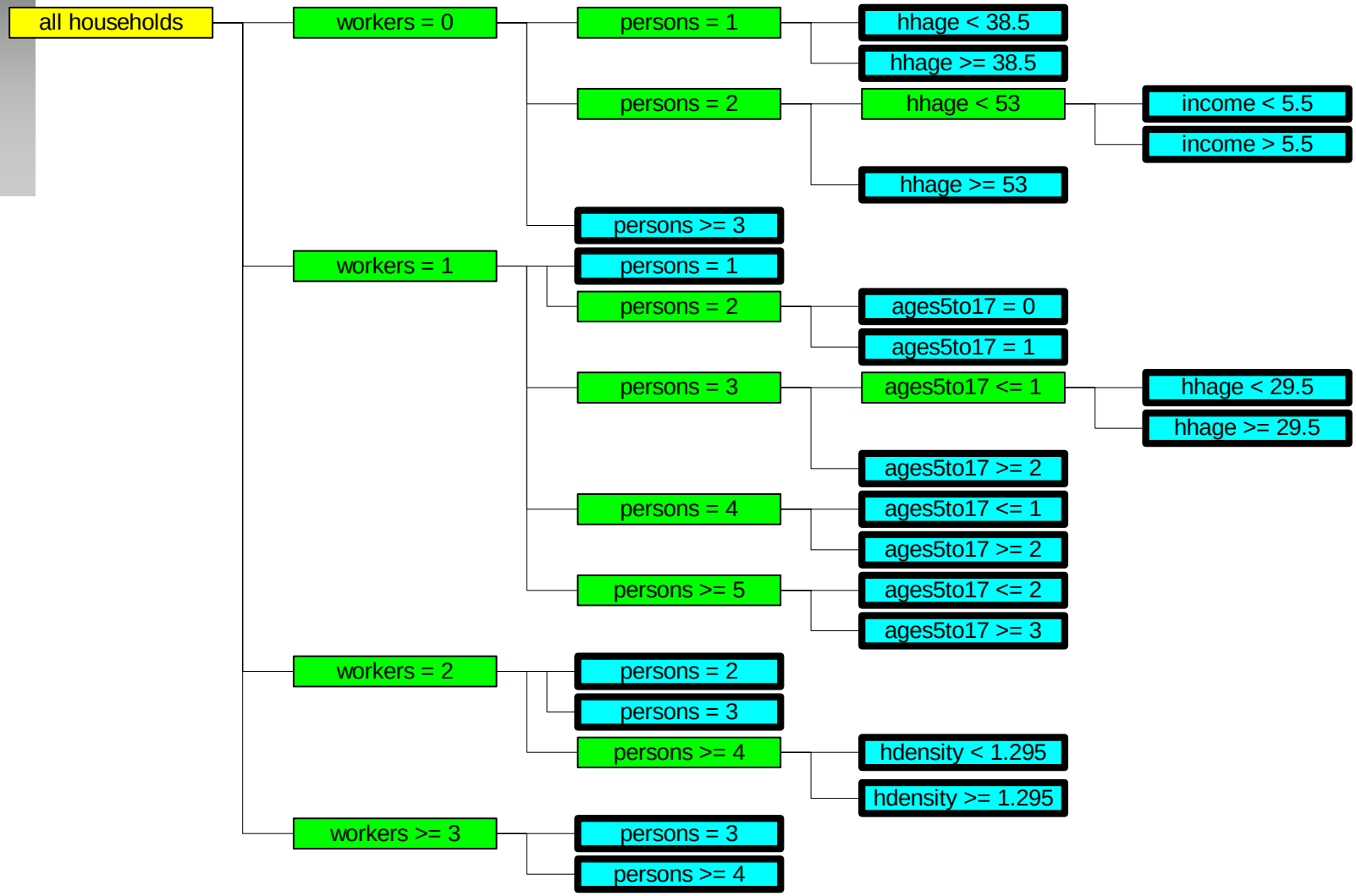
Activity Generator: Data Flow



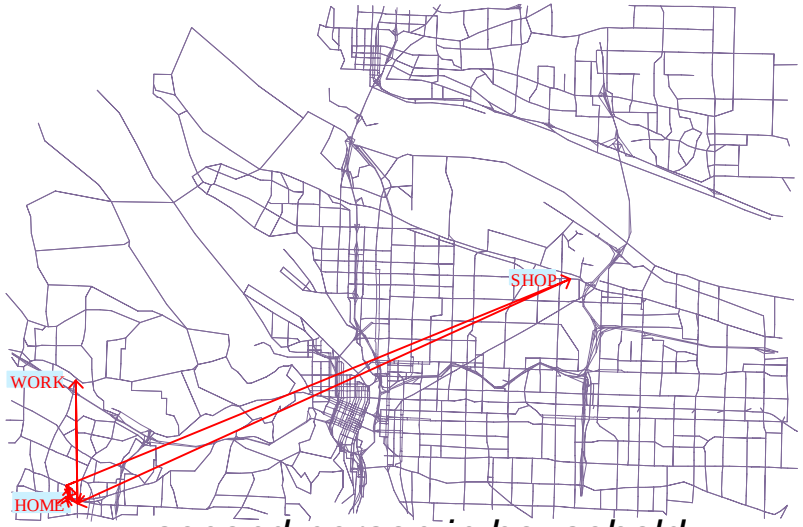
Activity Generator: Algorithm



Example Prediction Tree Using Household Demographics

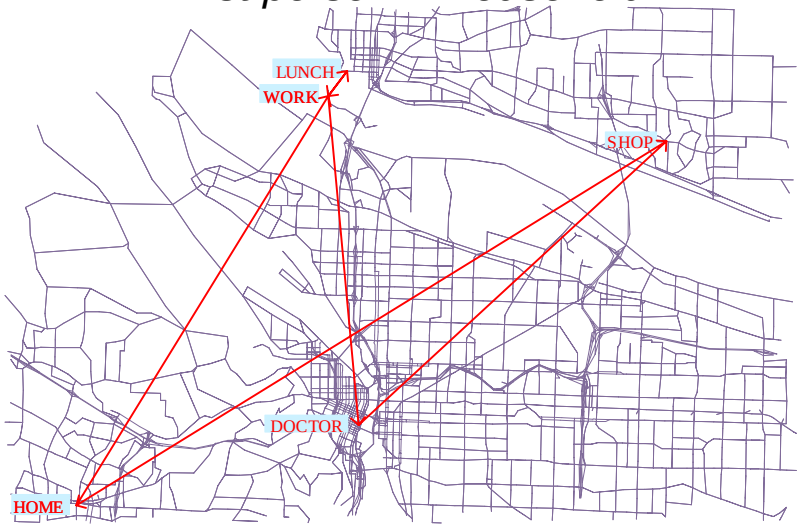


Example Activities in Portland, Oregon



second person in household

first person in household

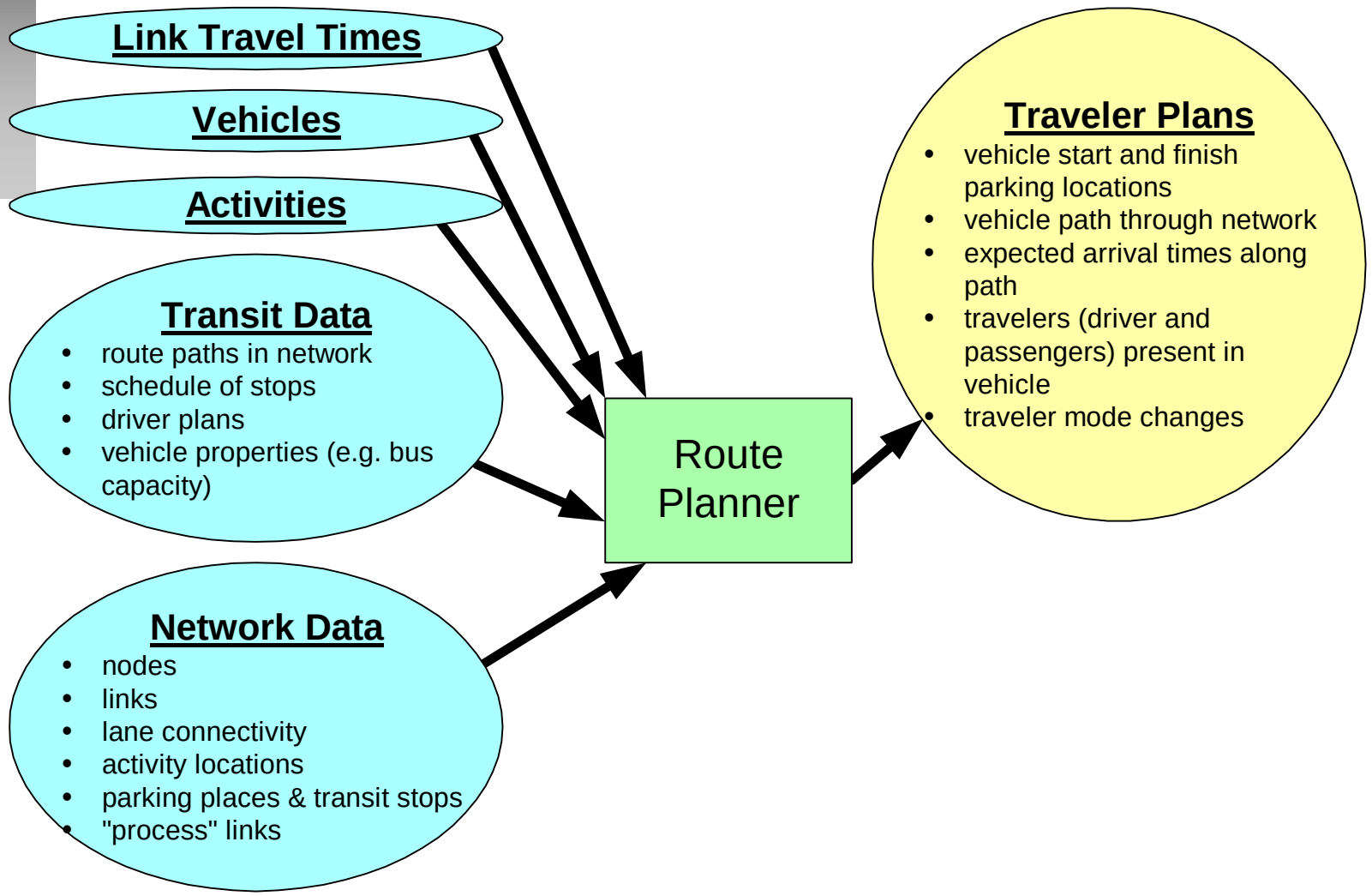


Route Planner: Purpose

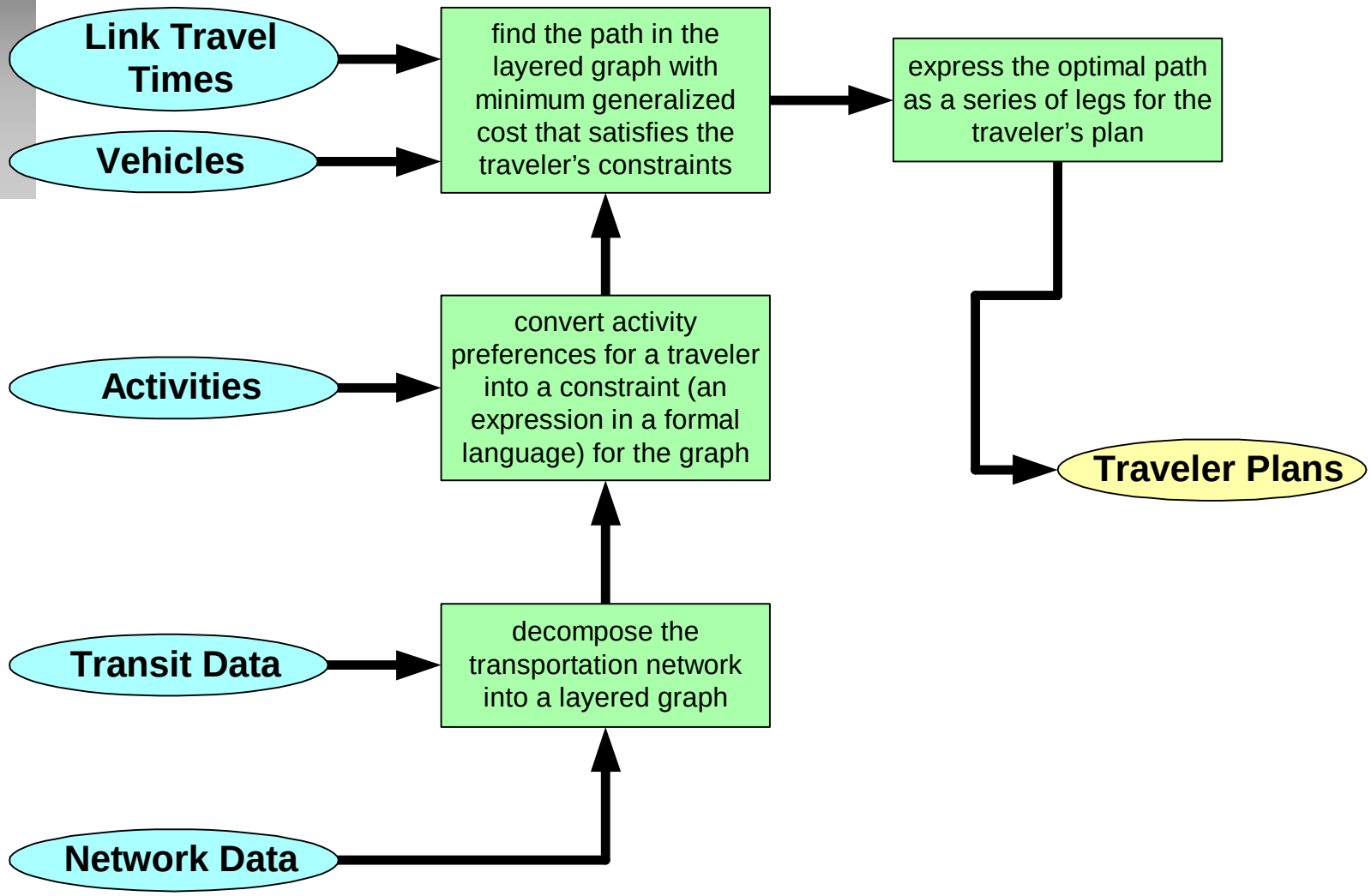
- *generates regional individual activity-based travel demand by assigning . . .*
  - *activities*
  - *modes*
  - *routes*

  to individuals in the form of trip plans
- *trip plan is a sequence of . . .*
  - *modes*
  - *routes*
  - *planned departure and arrival times at origins, destinations, and mode changing facilities*
- *trip plan selection related directly to each individual's goals*
- *individual trip plans form basis for traffic simulation that accounts for interactions among travelers*

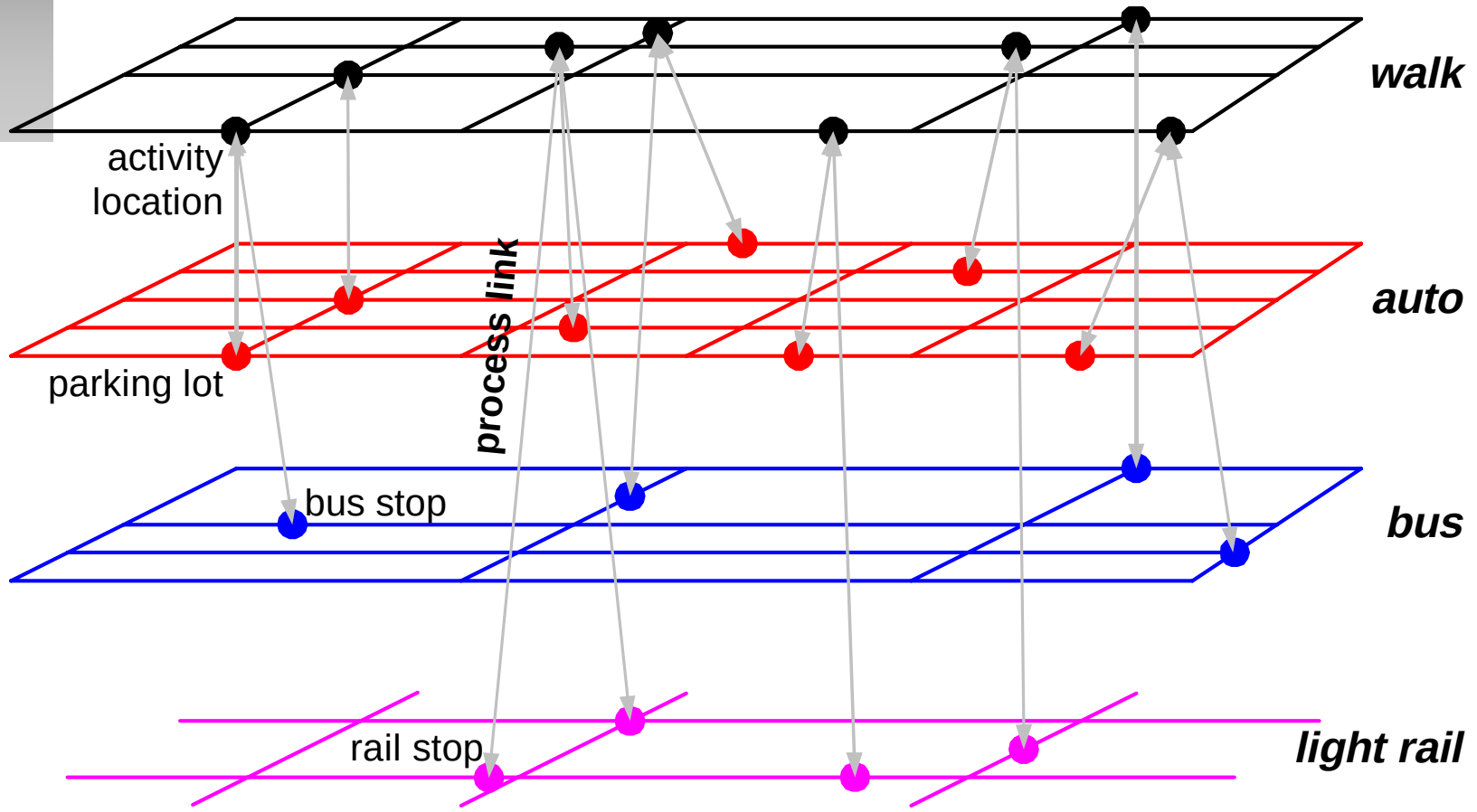
Route Planner: Data Flow



Route Planner: Algorithm

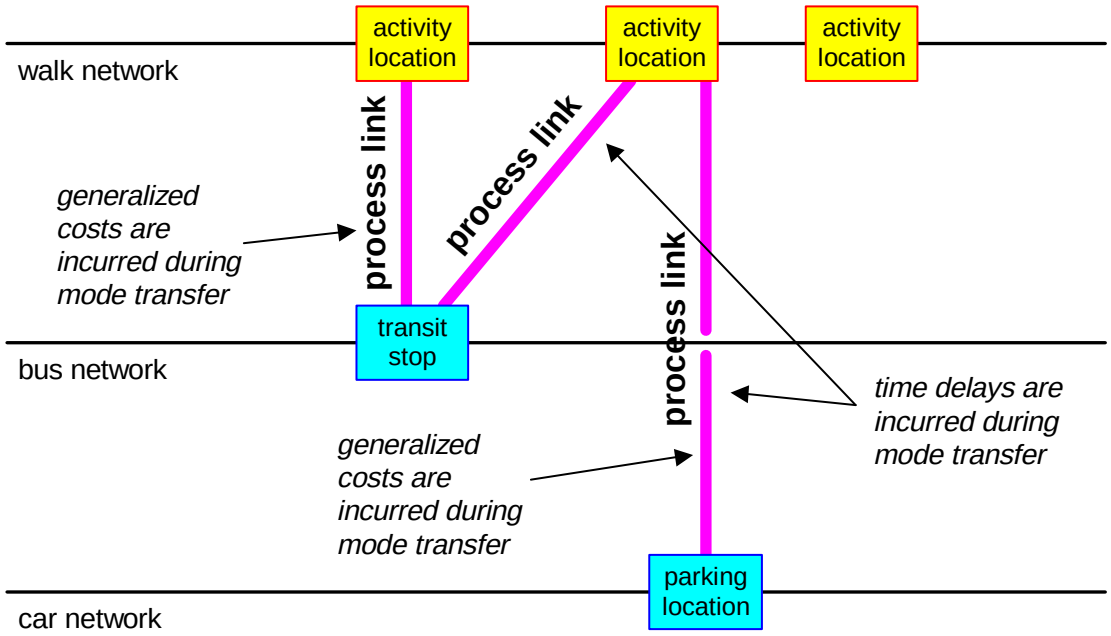


Example Layered Multi-Modal Network

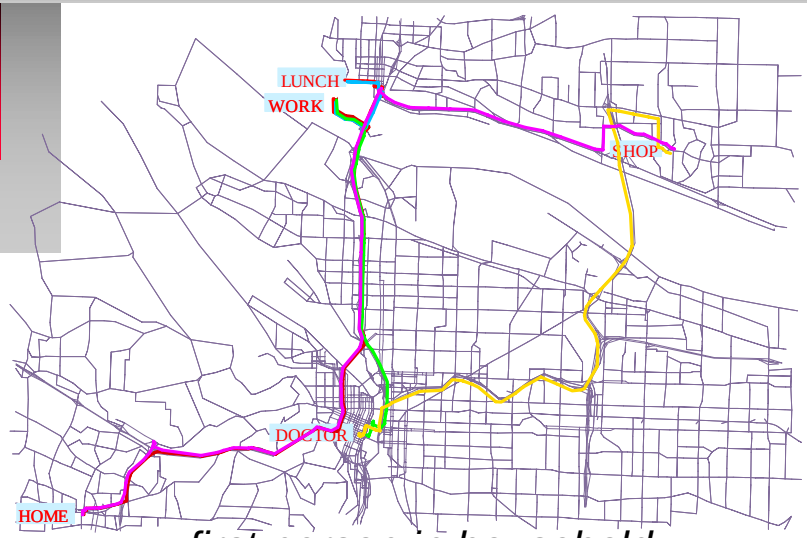


Formal Language for Mode Preferences

- *Symbols represent different modes:*
  - *w = "walk," c = "car," b = "bus," l = "light rail," t = (b|l) = "bus or light rail"*
- *A series of symbols expresses a mode preference:*
  - *wcw = "walk, then drive a car, then walk"*
  - *wctw = "walk, then drive to a transit stop, then take transit, then walk"*
  - *blb = "ride bus, then transfer to light rail, then ride bus"*
  - *w = "only walk"*
- *Each mode transfer passes through a process link where time and other costs are incurred.*

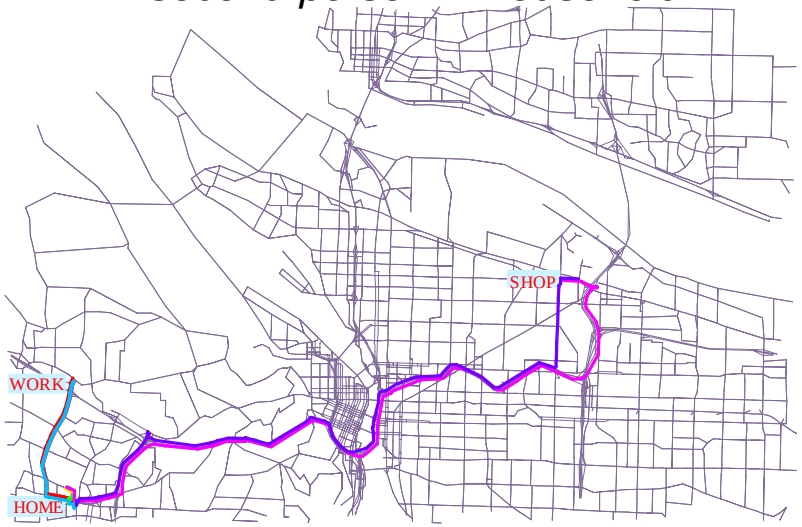


Example Route Plans in Portland, Oregon

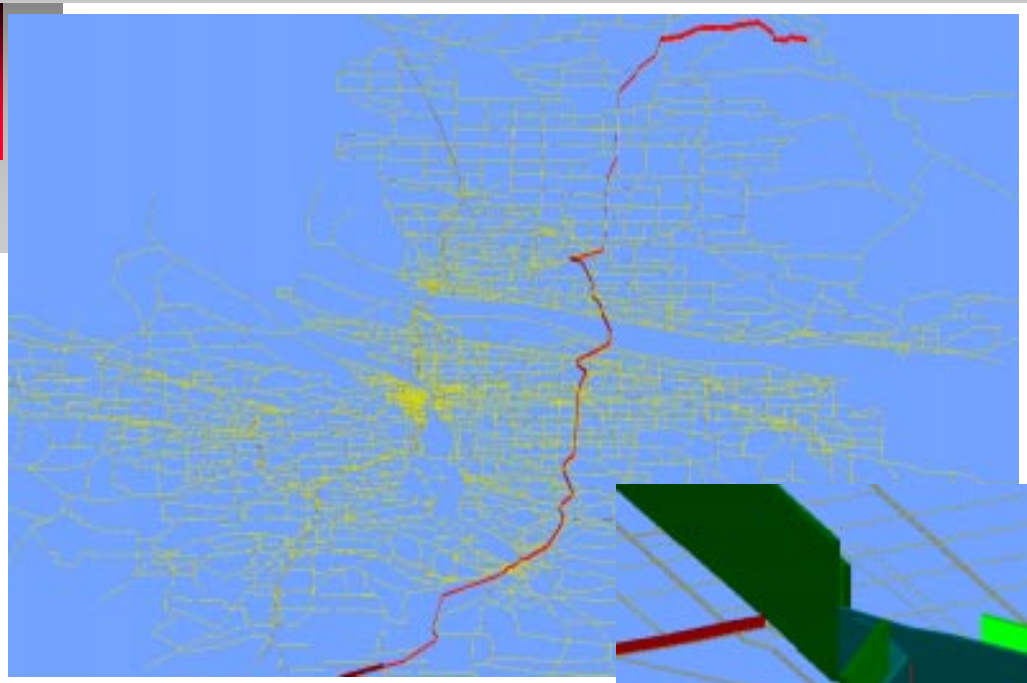


first person in household

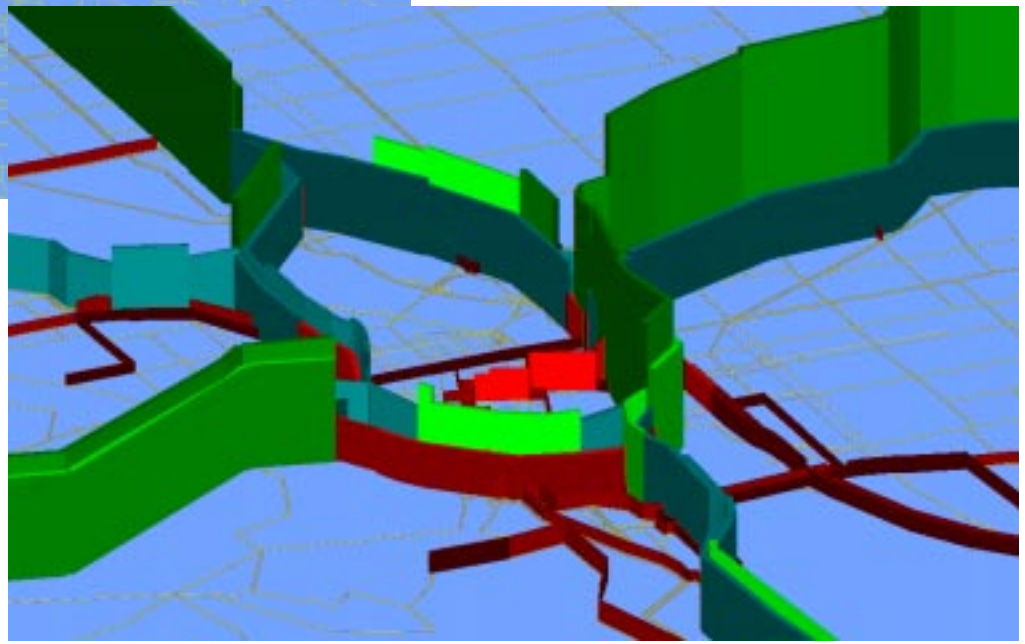
second person in household



Example Route Plans in Portland, Oregon



← single plan

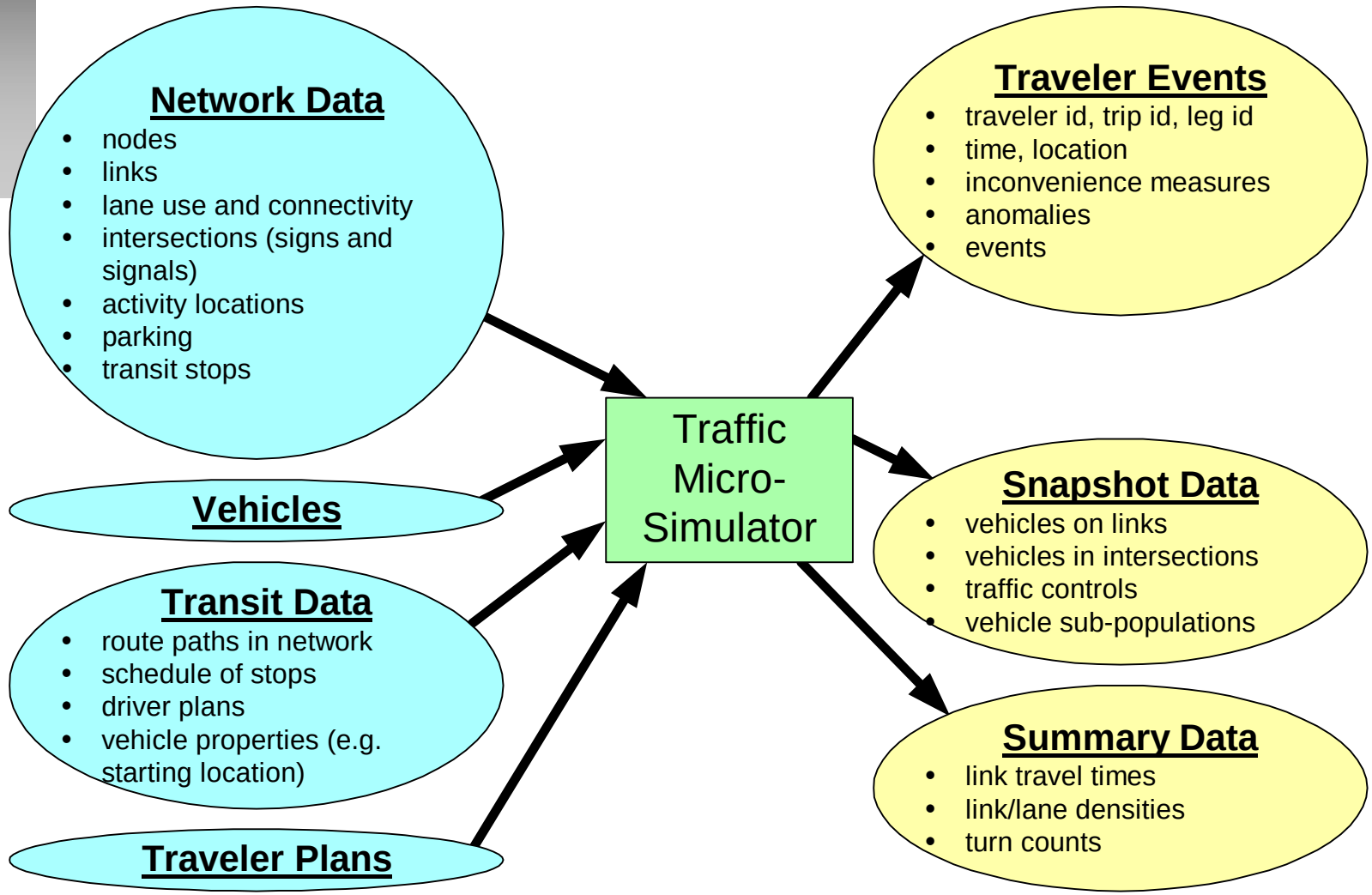


plan volumes →

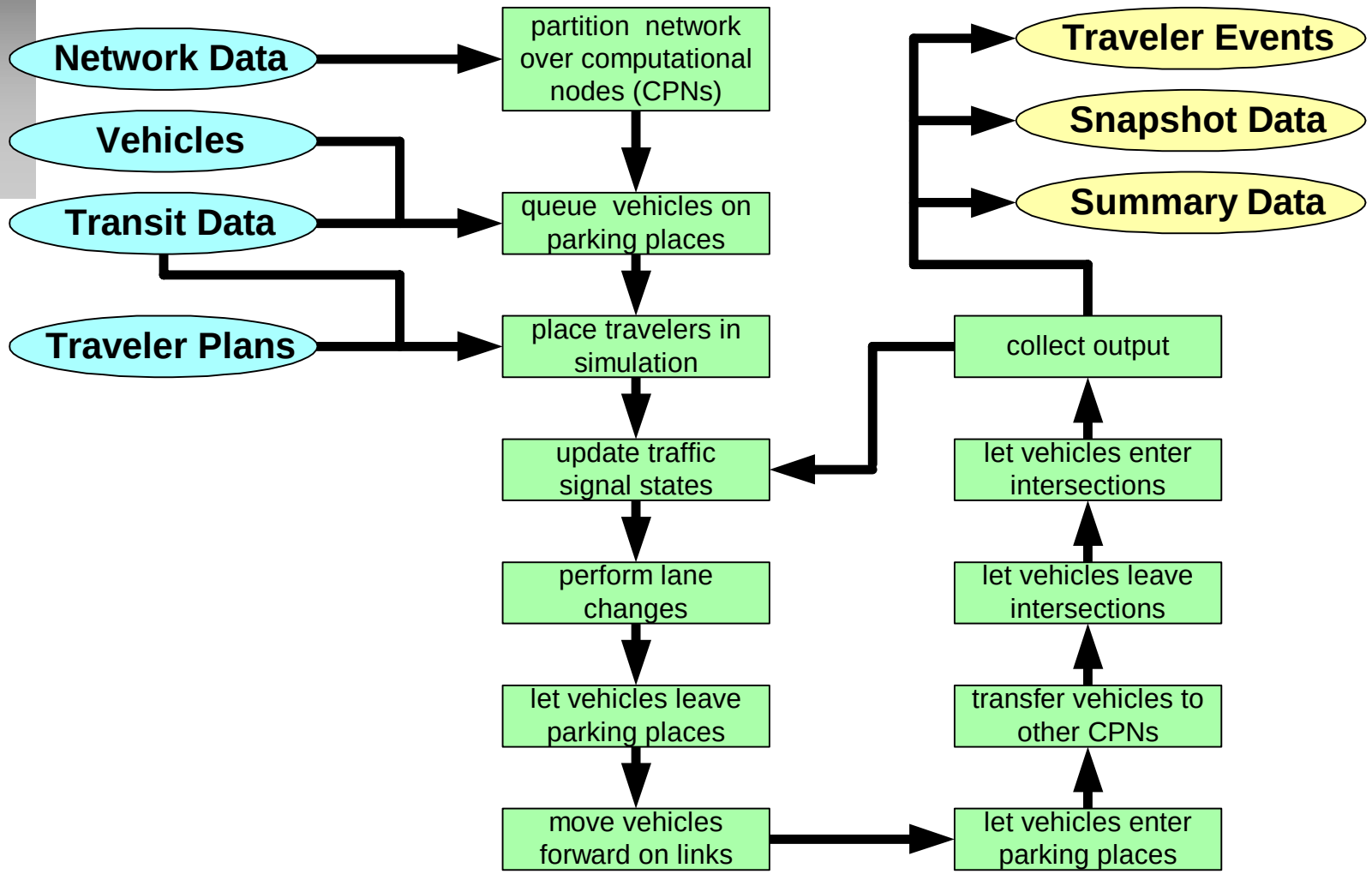
Traffic Microsimulator: Purpose

- *simulates the movement and interactions of travelers throughout a metropolitan region's transportation system*
  - *executes travel plans provided by the Route Planner*
  - *computes the overall intra- and inter-modal transportation system dynamics*
- *combined traveler interactions produce emergent behaviors such as traffic congestion*
- *microsimulation output forms basis for environmental calculations and for iteration decision-making*

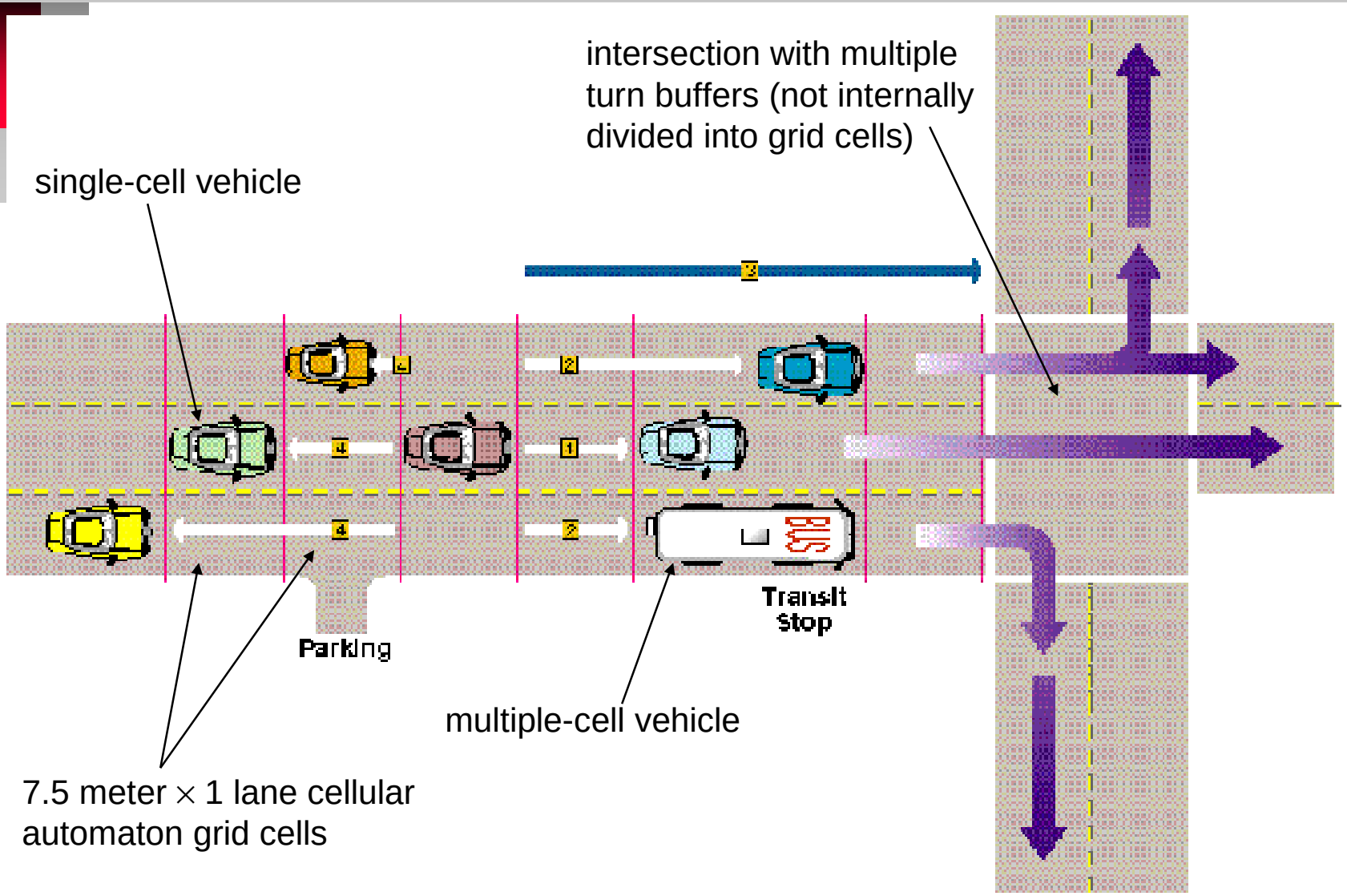
Traffic Microsimulator: Data Flow



Traffic Microsimulator: Algorithm



Cellular Automaton Microsimulation

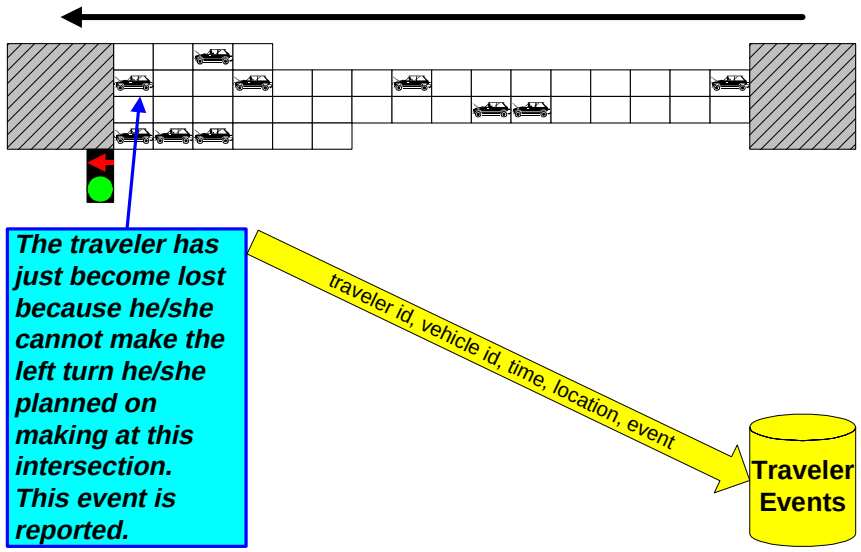


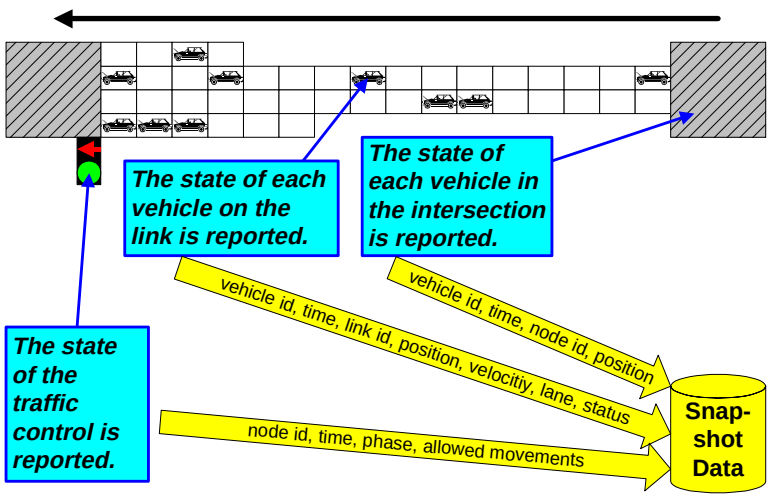
Cellular Automaton Driving Rules

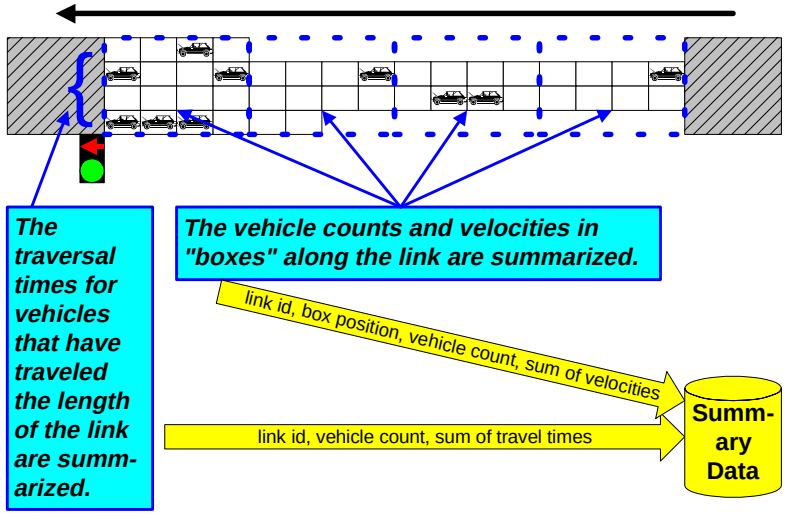
- *movement forward on grid based on . . .*
  - *gap to next vehicle*
  - *current speed*
  - *maximum speed*
- *lane changes based on . . .*
  - *chosen approach lane to next intersection*
  - *current speed*
  - *gap to next vehicle in current lane*
  - *gaps to previous and next vehicles in new lane*

  (additional special cases for turn and merge pocket lanes)
- *intersection entry based on . . .*
  - *position/speed on link*
  - *occupancy of intersection buffer*
  - *state of oncoming/interfering traffic*
- *total of about twelve adjustable parameters for driving rules*

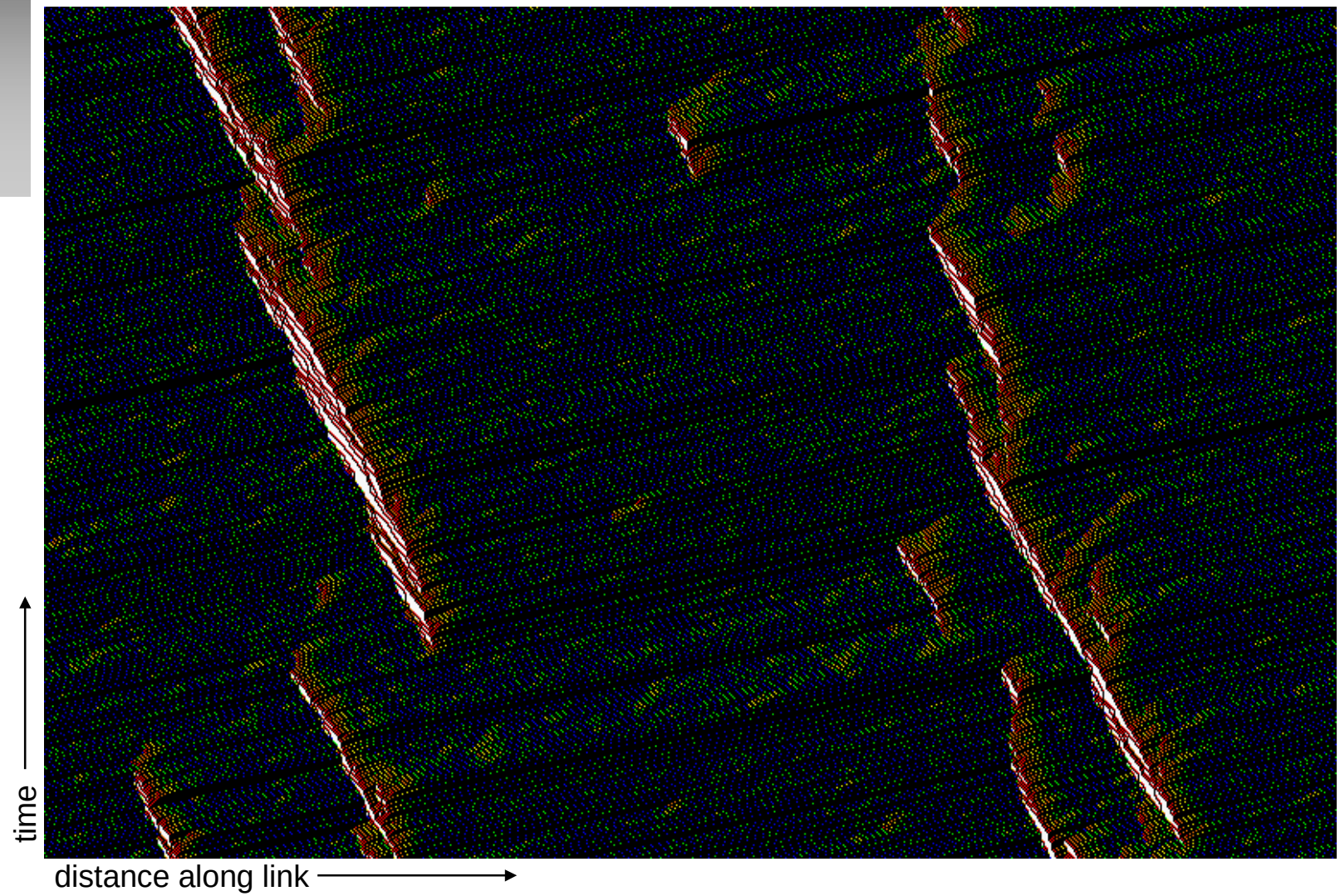
Traffic Microsimulator: Output Types



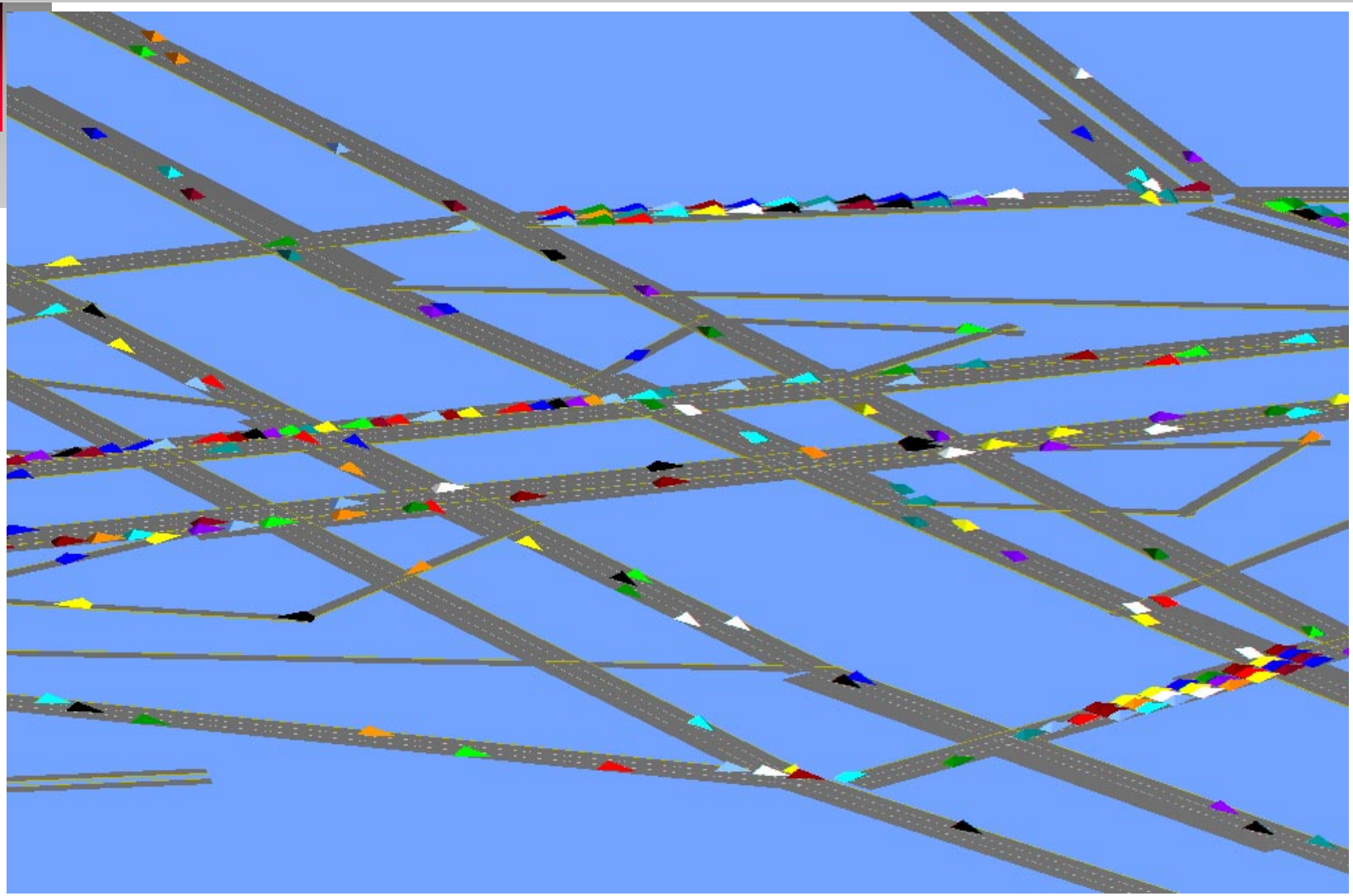




Example Vehicle Trajectories



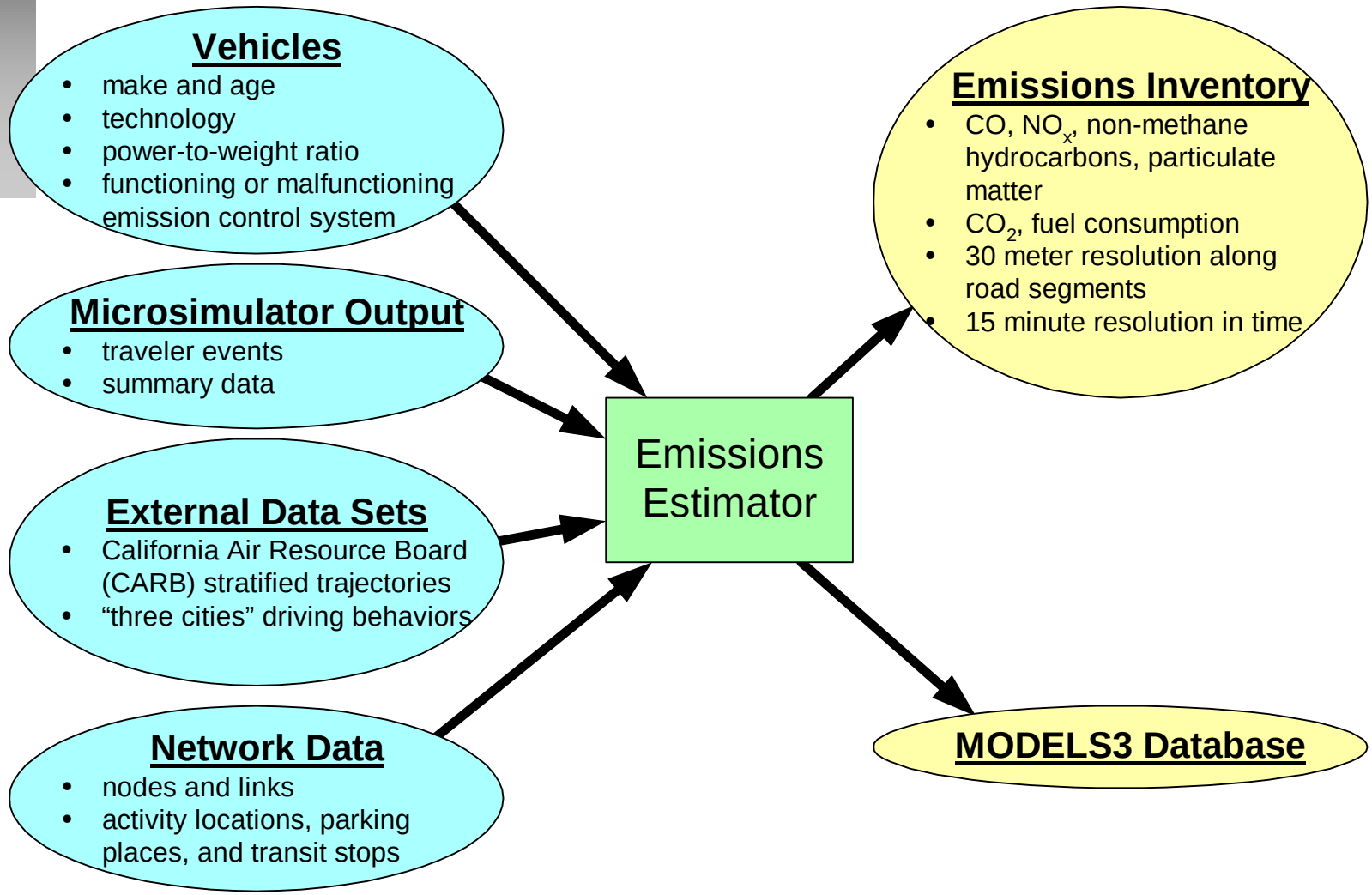
Example Traffic for Dallas, Texas



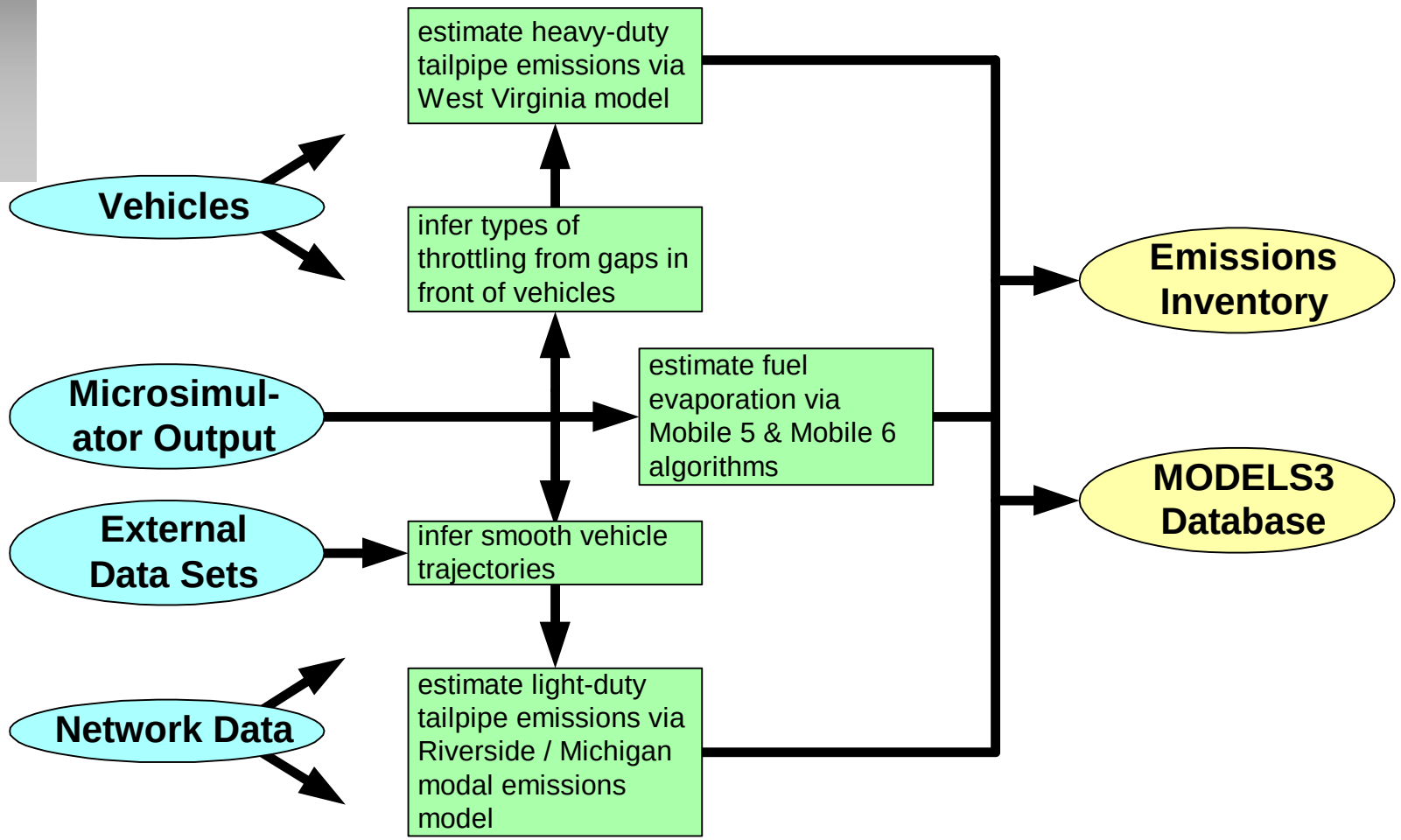
Emissions Estimator: Purpose

- *translates traveler behavior into consequent . . .*
  - *air quality*
  - *energy consumption*
  - *pollutant emissions*
- *produces estimates of tailpipe and evaporative emissions for light- and heavy-duty vehicles as a function of vehicle . . .*
  - *fleet composition*
  - *status*
  - *dynamics*
- *emissions output forms basis for the computation of pollutant concentrations, atmospheric conditions, local transport and dispersion, and chemical reactions*

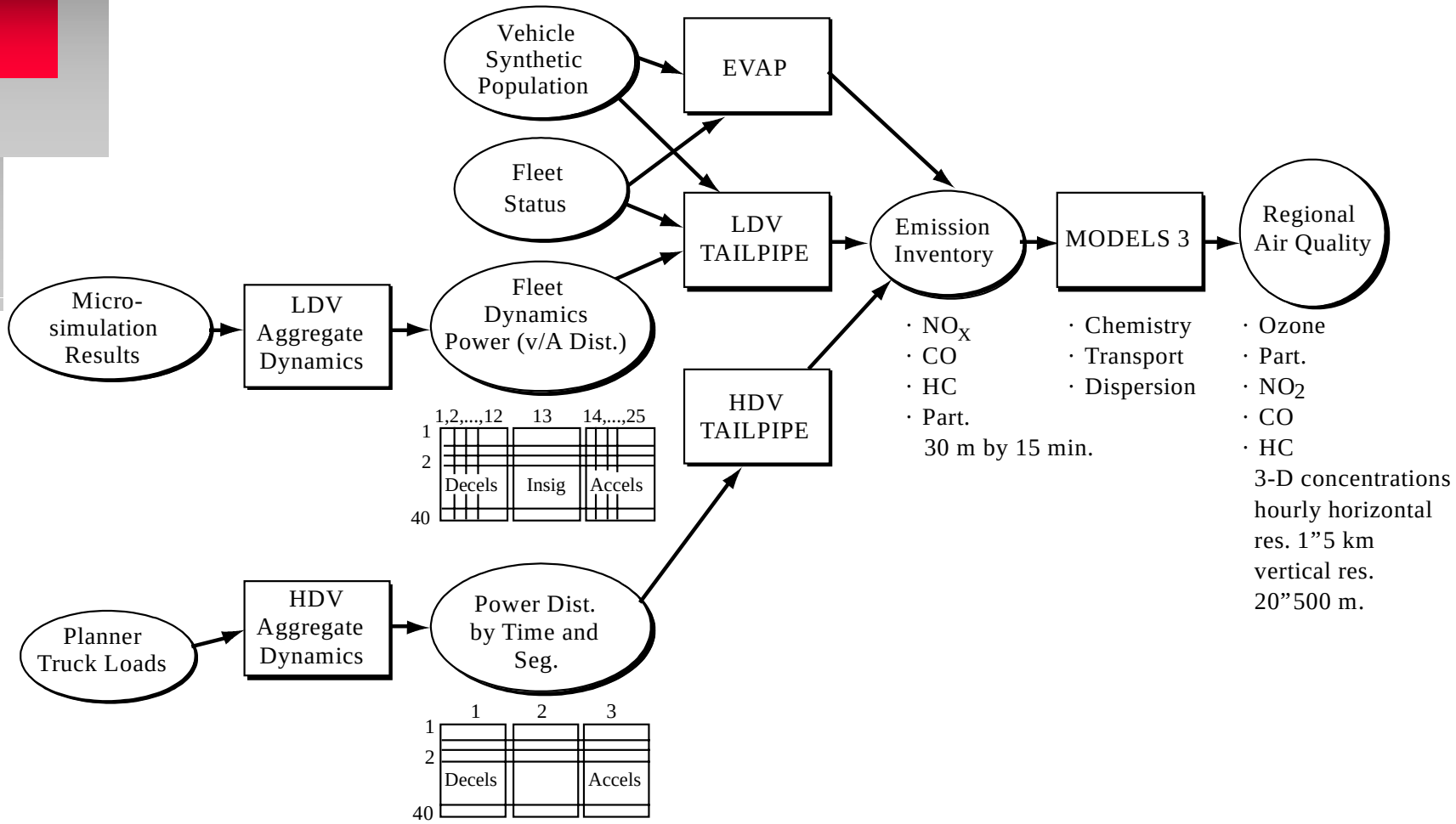
Emissions Estimator: Data Flow



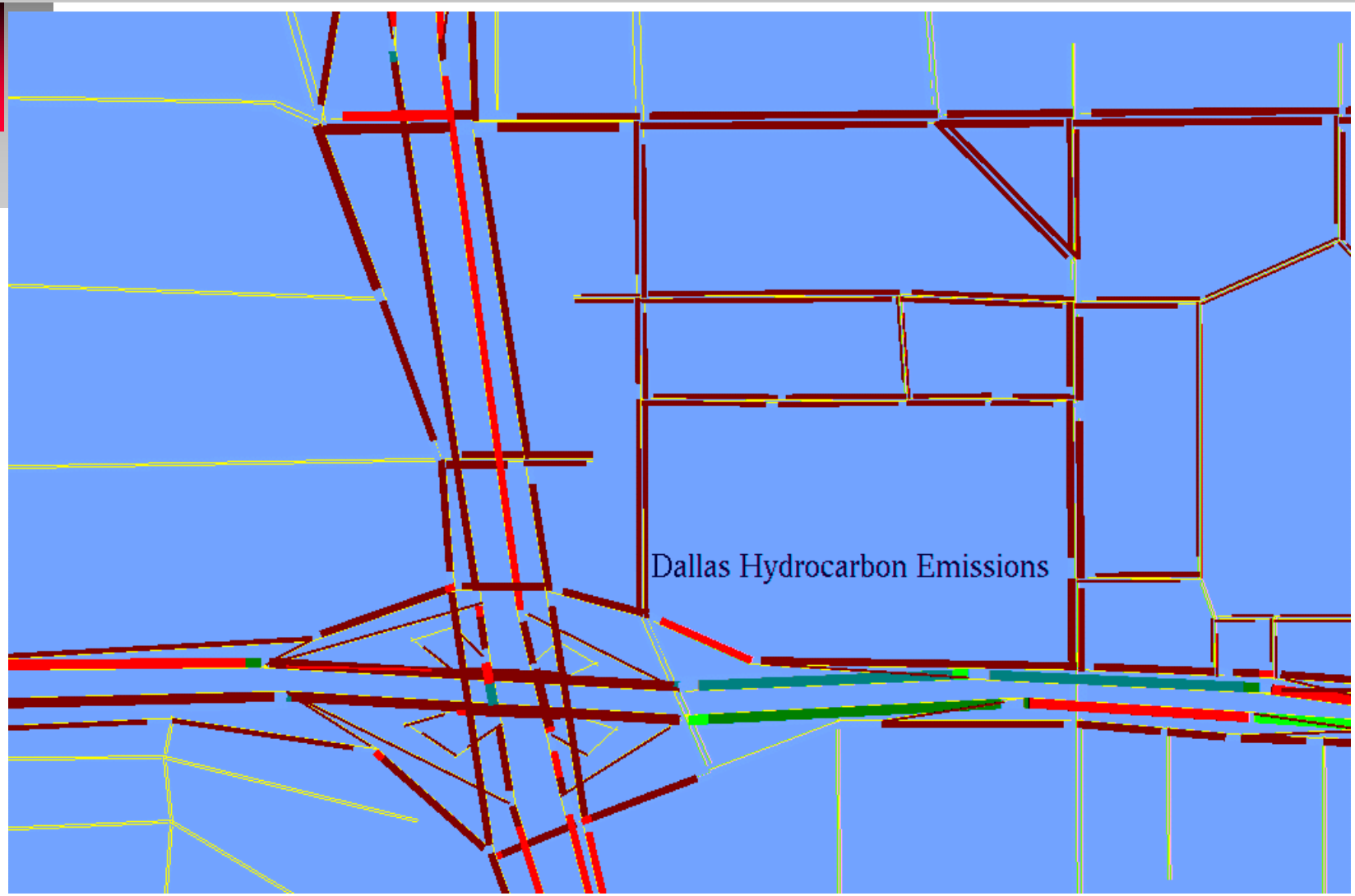
Emissions Estimator: Algorithm



Emissions Estimator Details



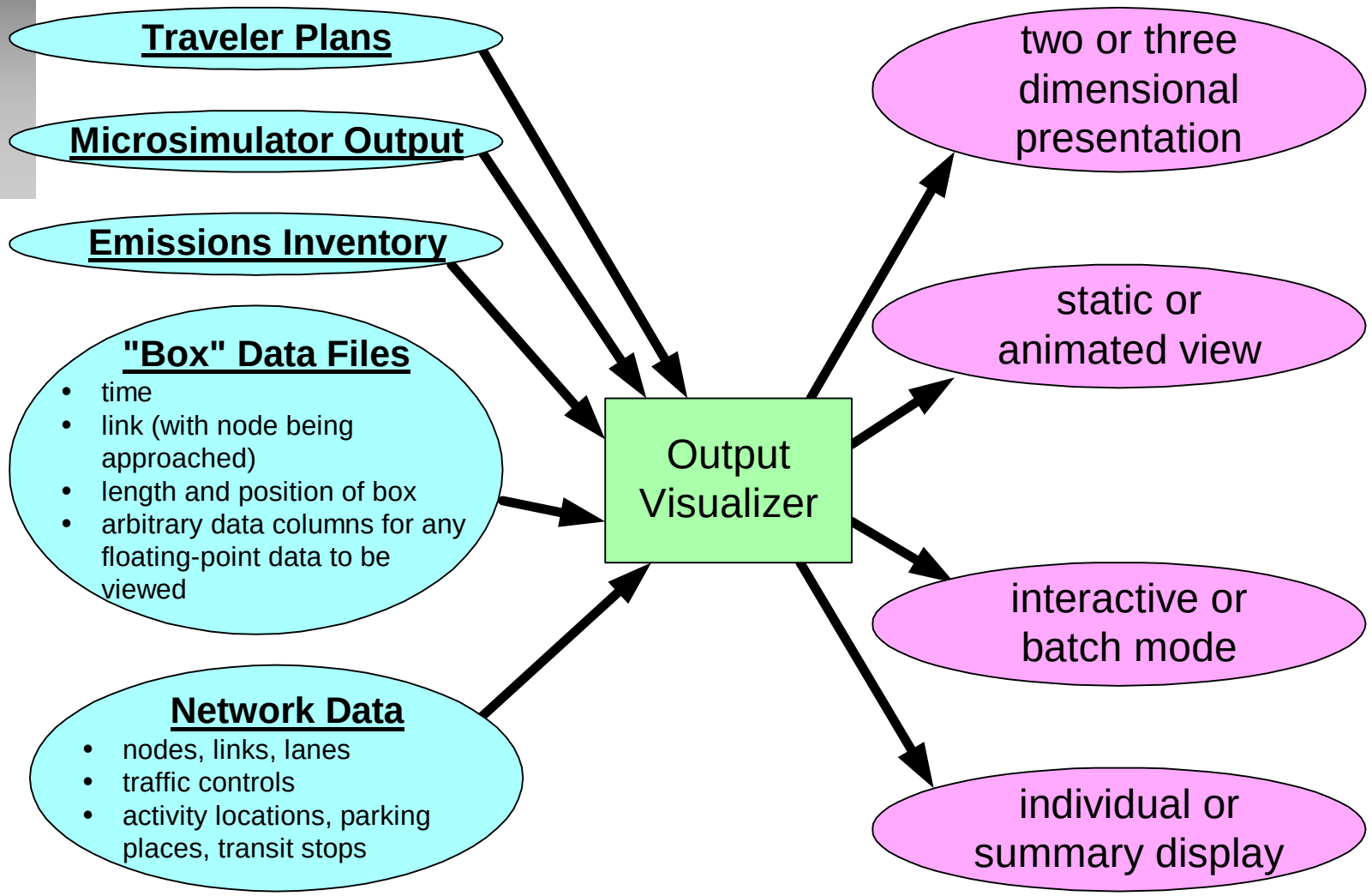
Example Hydrocarbon Emissions in Dallas, Texas



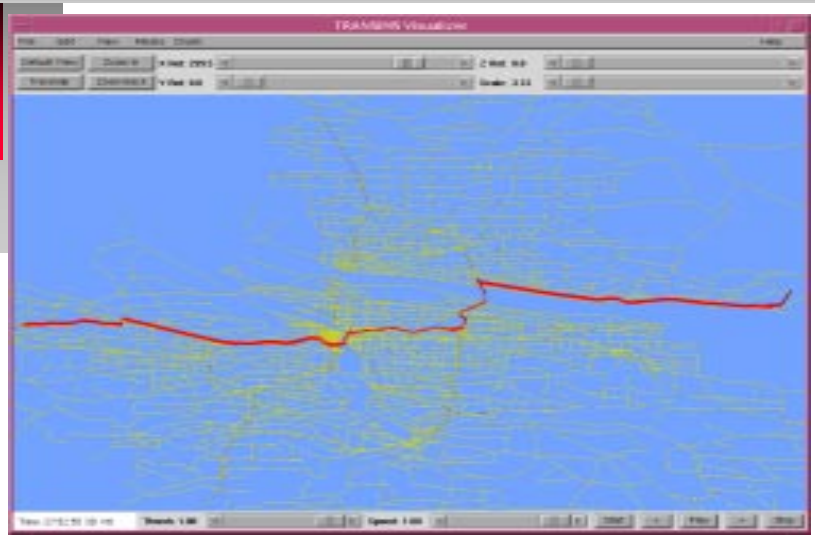
Output Visualizer: Purpose

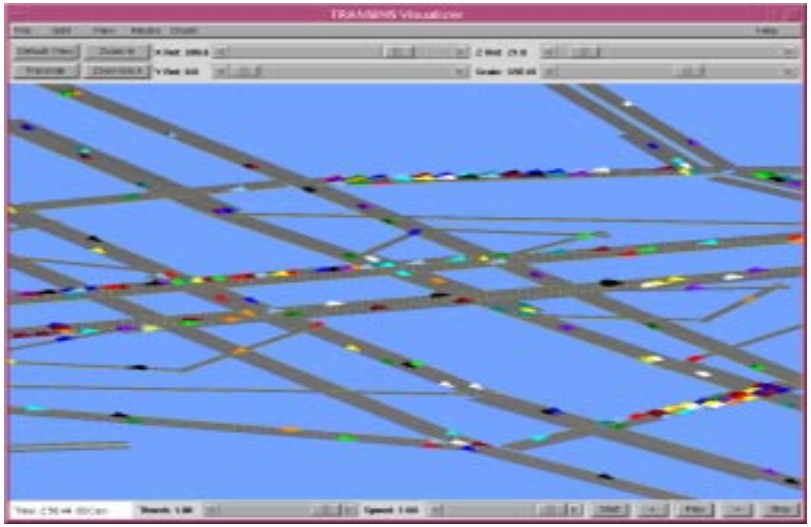
- *allows an analyst to view and animate data generated by any other TRANSIMS module*
- *provides a unified and flexible means for exploring the voluminous output data potentially available*

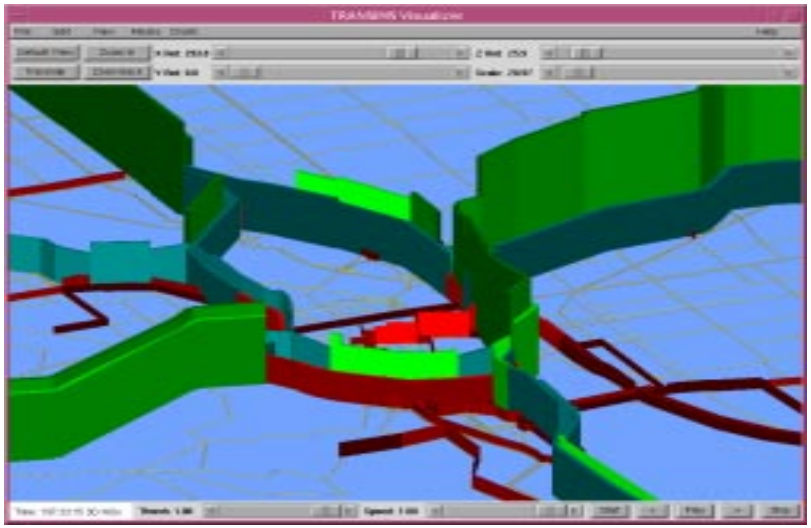
Output Visualizer: Data Flow



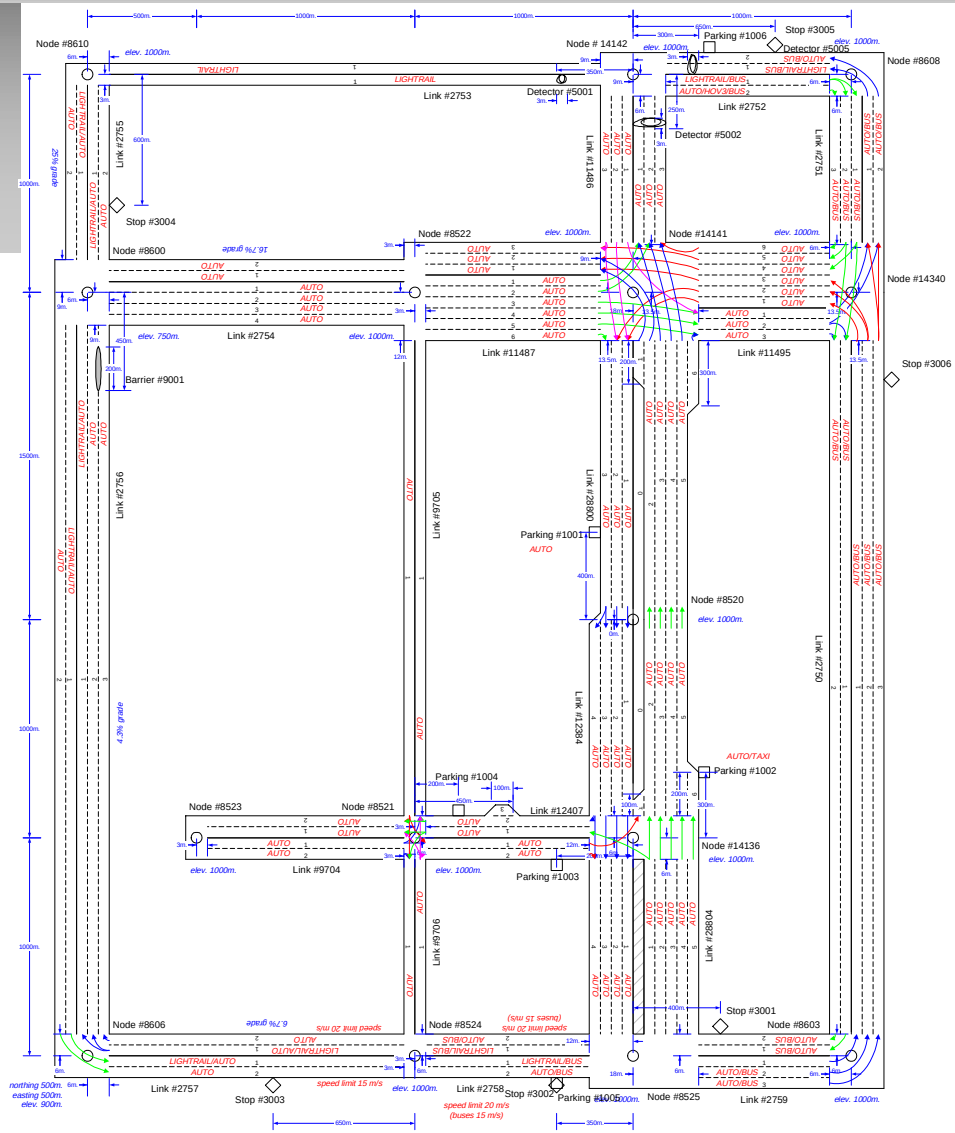
Example Output Visualization





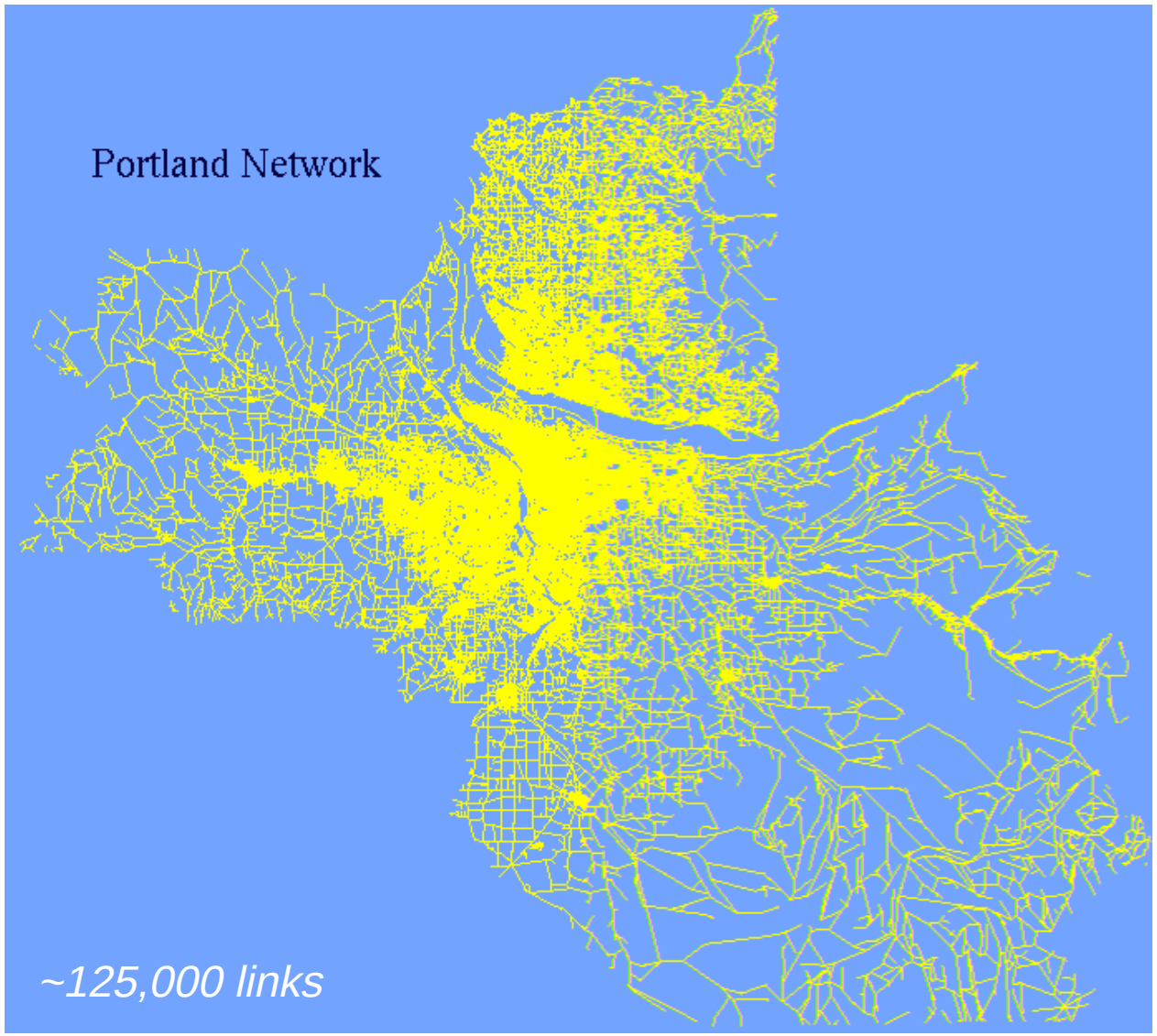


TRANSIMS Network Data



- *nodes*
- *links*
  - *grade*
  - *mode*
  - *functional class*
- *lanes*
  - *restrictions*
  - *connectivity*
- *intersections*
  - *setbacks*
  - *signs*
  - *signals (rings, entries)*
- *parking places*
- *transit stops*
- *activity locations*
  - *land use*
  - *employment*
- *“process” links*

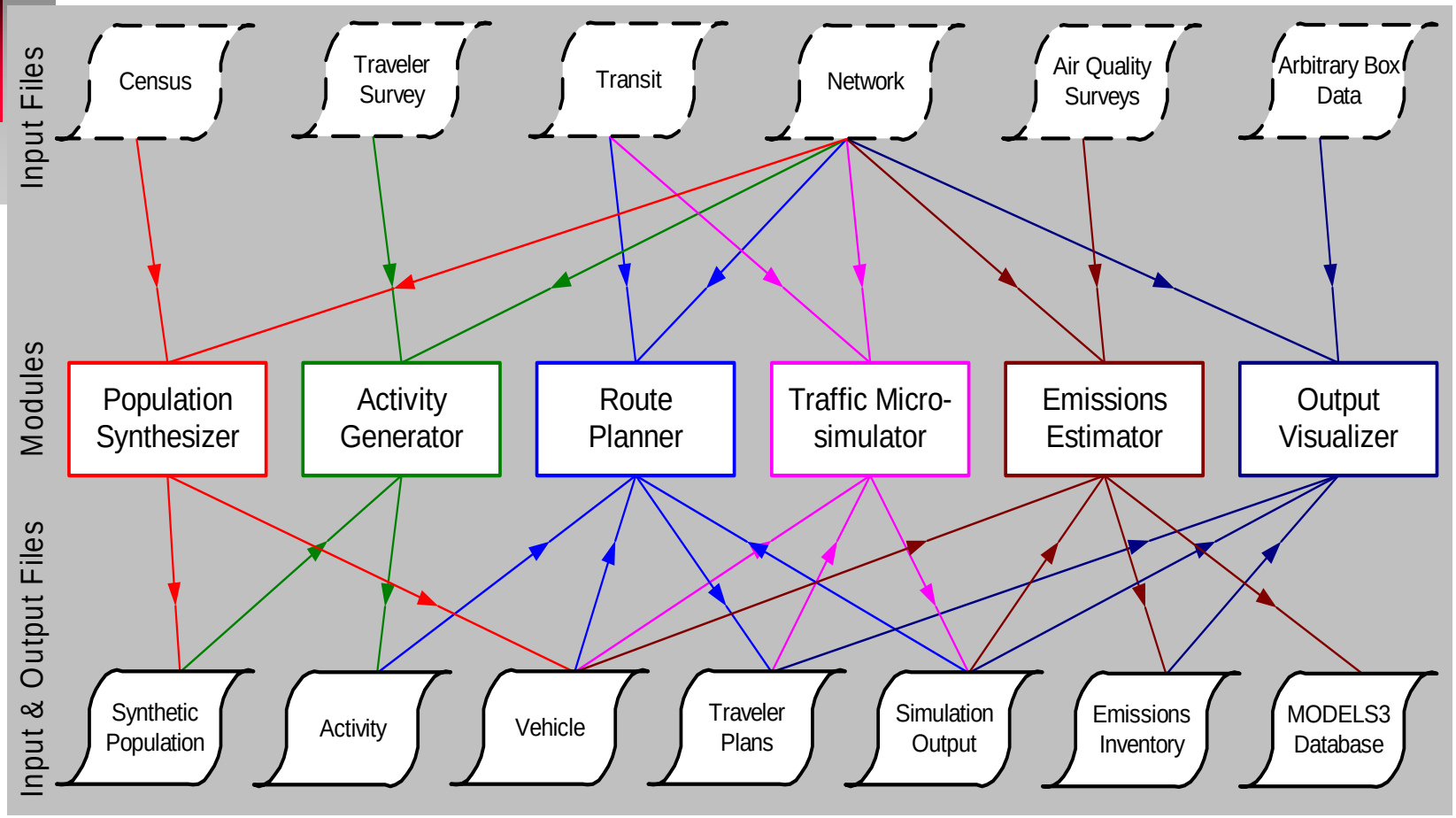
Example Network for Portland, Oregon



TRANSIMS Software Modules

- *general characteristics*
  - *can be treated as “black boxes”*
  - *simple invocation*
  - *well-defined parameter sets*
  - *well-defined input/output file specifications*
- *several currently available*
  - *population synthesizer*
  - *activity generator*
  - *route planner*
  - *traffic microsimulator*
  - *emissions estimator*
  - *output visualizer*
- *alternate modules performing identical functions (but using different algorithms) can coexist*
- *completely new types of modules can be created*

Data Flow for Current TRANSIMS Modules



- *A TRANSIMS **selector** and **iteration script** control when modules are run and how the data are routed between modules.*

TRANSIMS Framework

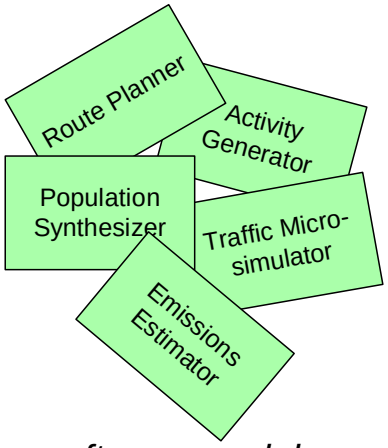
- *flexible software system*
- *for transportation planning studies/experiments*
- *supports the future growth of TRANSIMS technology*
- *building blocks*
  - *software modules*
    - *standardized command file*
    - *standardized input/output interface requirements*
    - *several major modules already available*
    - *third-parties may replace or add new conforming modules*
    - *reusable C++ libraries for building TRANSIMS objects (network, plan, activity, and simulation output)*
    - *high-performance, parallel/distributed computing*
  - *simulation data files*
    - *well-documented text formats*
    - *interface library callable from C, C++, FORTRAN, etc.*

TRANSIMS Framework (continued)

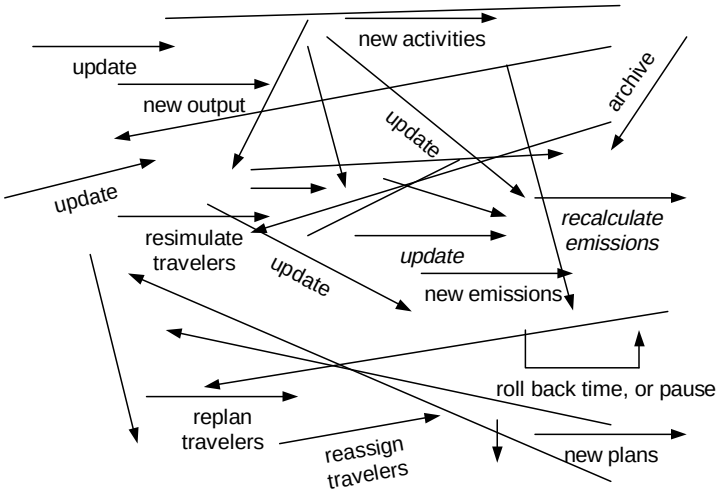
- *data manipulation tools*
  - *filtering, sorting, indexing, merging, searching, summarizing, "noising"*
  - *for standard data files*
- *tools for controlling iteration between modules*
  - *"iteration database" with history of iterations*
  - *"selector" controlling and supervising iteration process*
- *iteration "scripts"*
  - *define a study or experiment*
  - *predefined for typical studies*
    - *calibration*
    - *sensitivity analysis*
    - *convergence/equilibration of activities, plans, and traffic*

- *many possible combinations of above "building blocks"*
  ⇒ many possible realizations of TRANSIMS

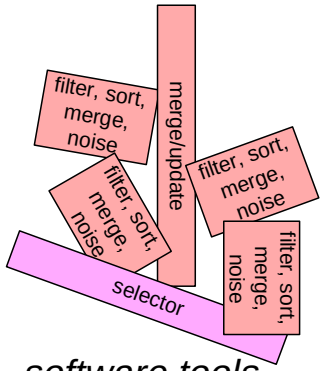
Building Blocks in the TRANSIMS Framework



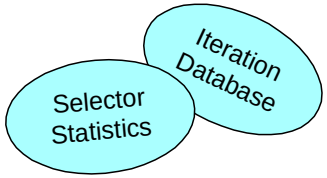
software modules



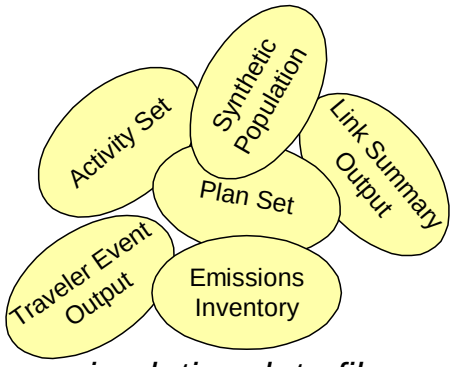
data flows



software tools

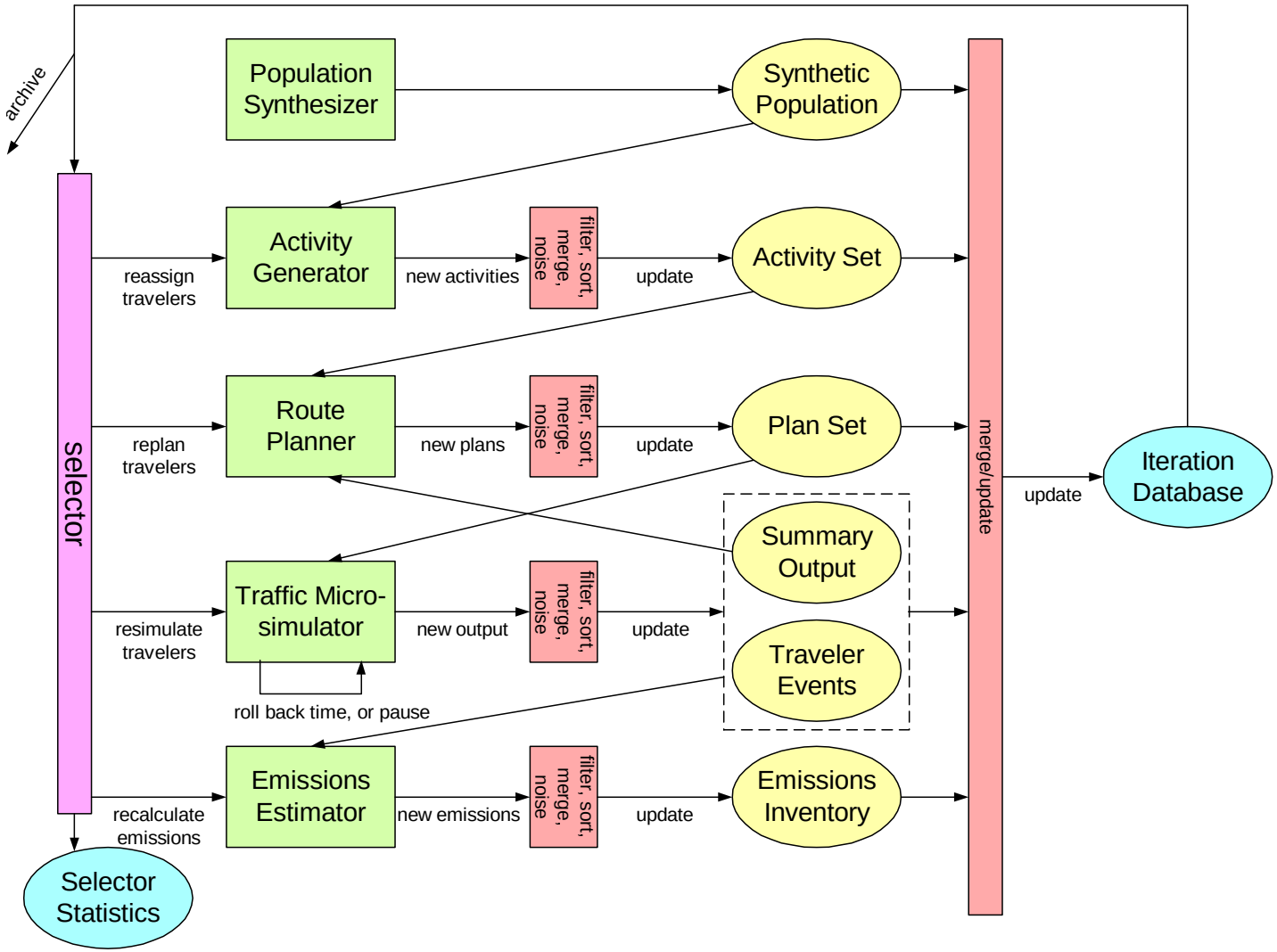


iteration data files



simulation data files

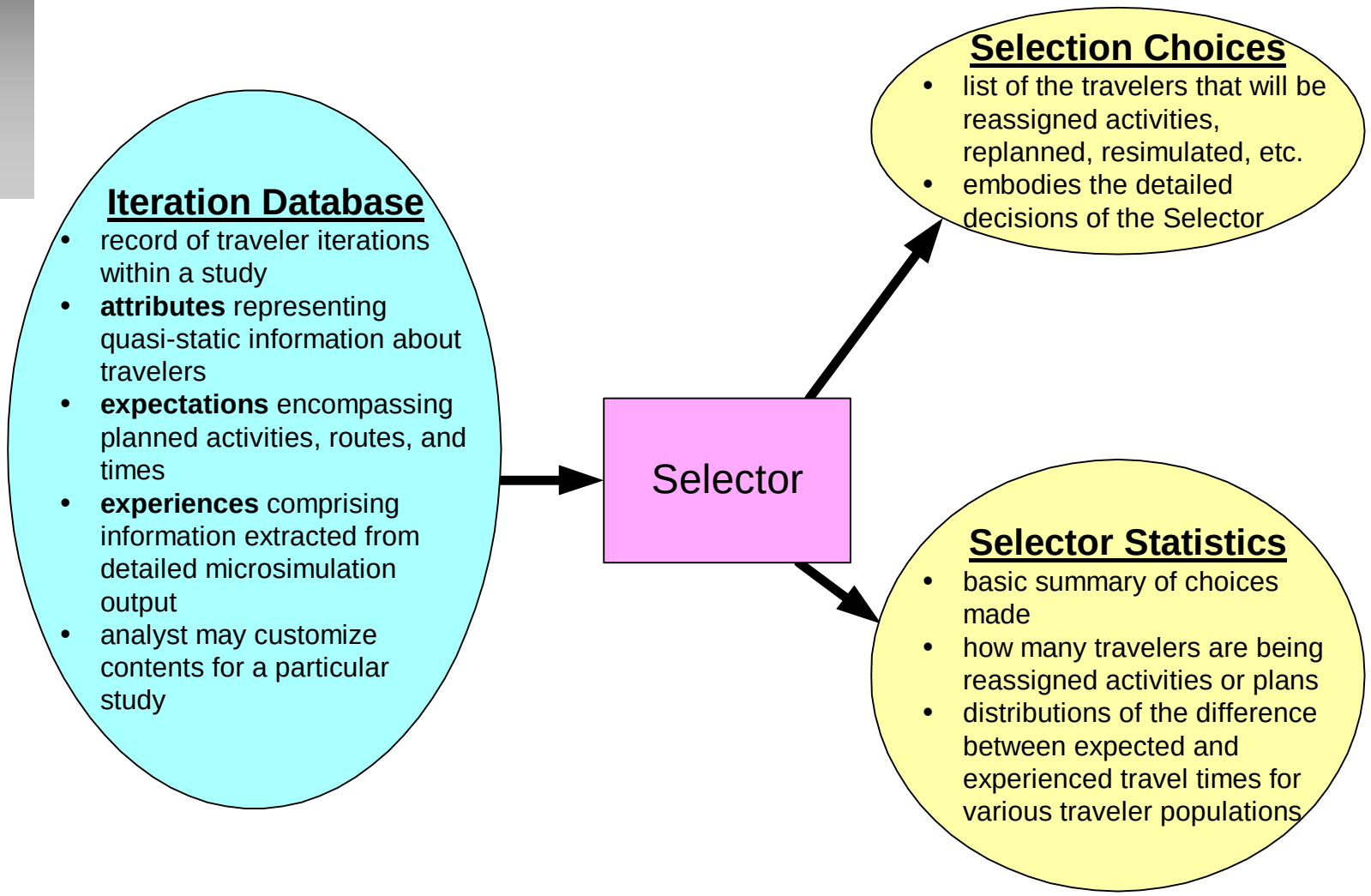
One Realization of TRANSIMS



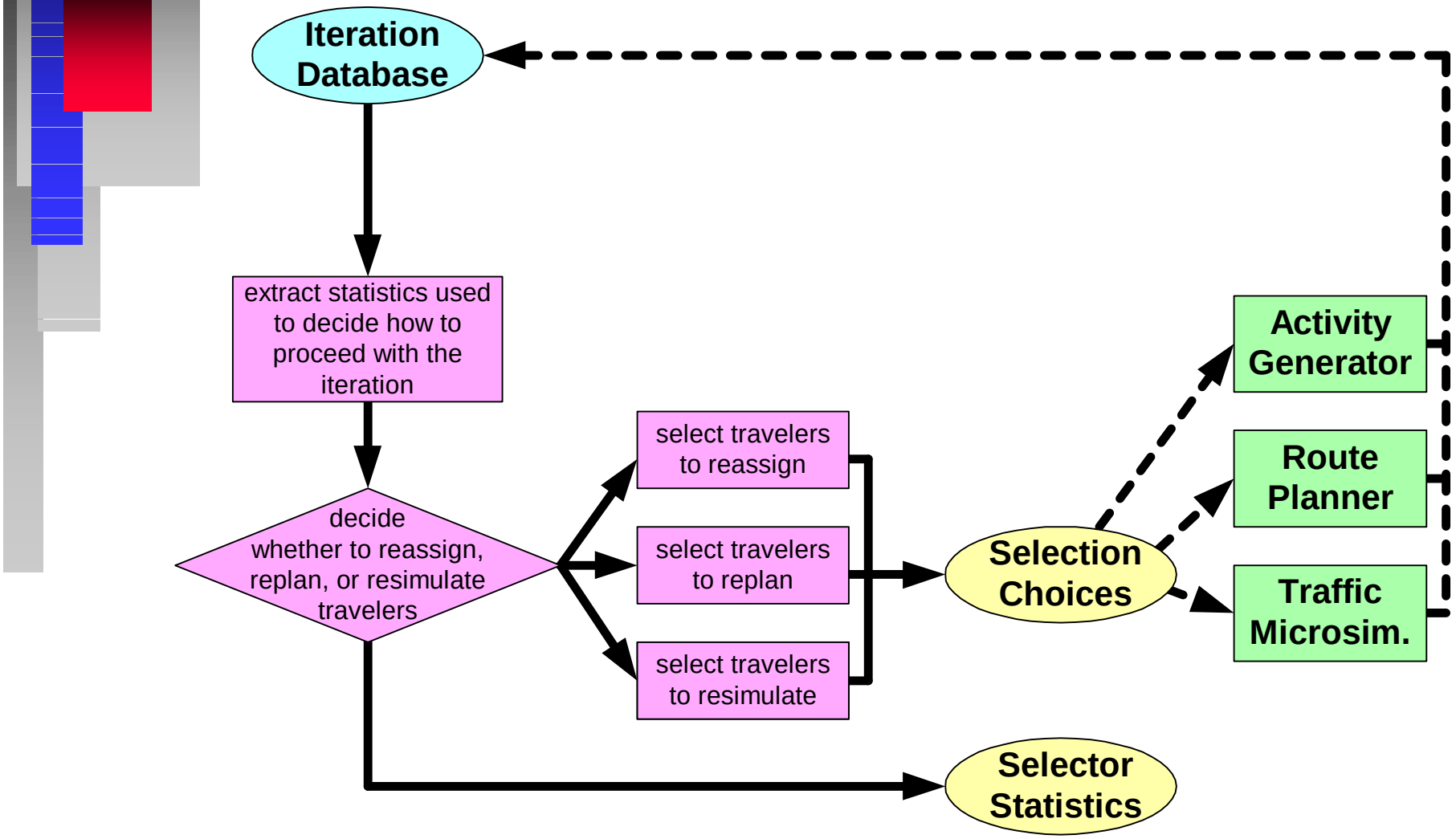
Selector: Purpose

- *controls when modules are run and how the data are routed between modules*
- *operates in conjunction with an "iteration script" that provides the top-level control for a series of TRANSIMS iterations*
- *no single, "standard" Selector component*
  - *different study designs involve different iteration schemes*
  - *a variety of Selectors have uses in different studies or other contexts*

Selector: Data Flow



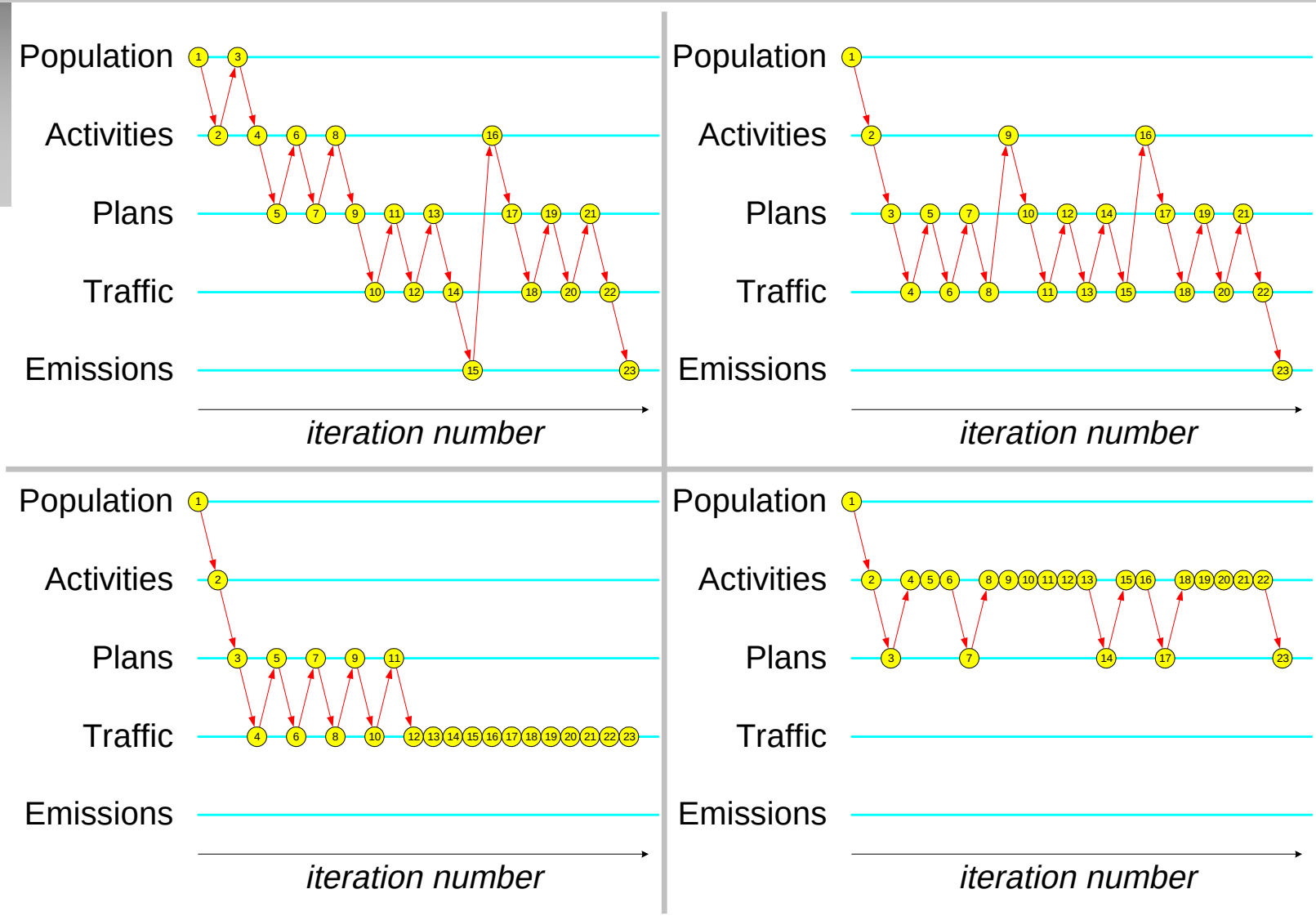
Selector: Generic Algorithm



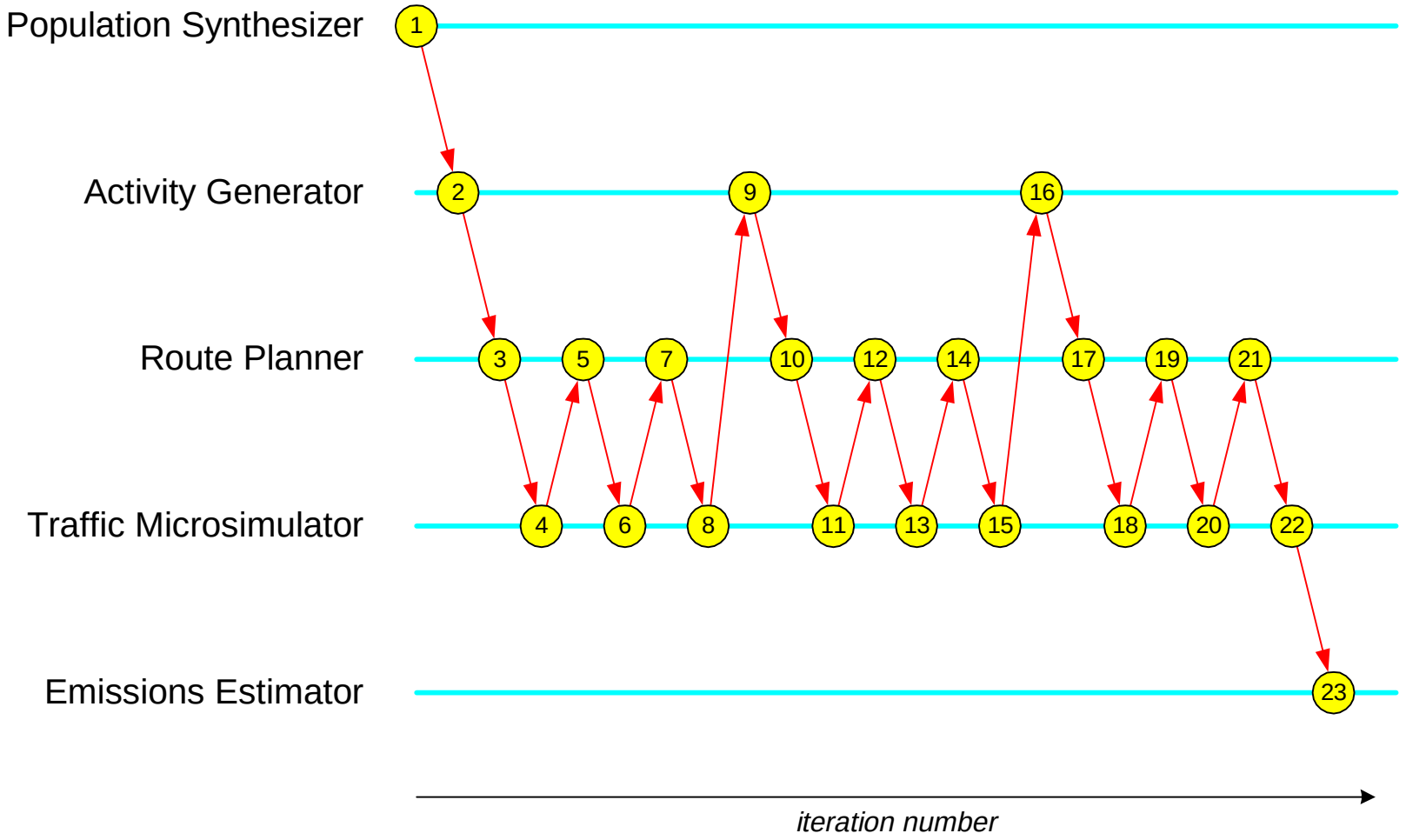
Example Selection Strategies

- ***replan routes*** *for travelers who have simulated travel times differing too much from their planned travel times*
- ***reassign activities*** *for households if any member is too late for work*
- ***average microsimulation output*** *from several runs*
- ***switch*** *to a higher fidelity* ***microsimulation*** *midway through the iteration process*
- ***reject*** *newly-generated* ***route plans*** *for some travelers based on their travel preferences*
- ***alter transit schedules*** *based on travel demand*
- ***adjust pricing*** *based on network congestion*
- ***mimic traveler information system*** *by adding different levels of random noise to feedback data for different travelers*
- ***change selector*** *to be used in next iteration*

Four Example Iteration Schemes



Example Study: Strategy for Iterations



Example Study: Selector

- *for iteration 1 . . .*
  - *request that the **population synthesizer** be run*
- *for iterations 2, 9, 16 . . .*
  - *read the **iteration database***
  - *identify **households** containing travelers more than 15 minutes late for their work activity*
  - *request that the **activity generator** be run for those households*
- *for iterations 3, 5, 7, 10, 12, 14, 17, 19, 21 . . .*
  - *read the **iteration database***
  - *identify **travelers** more than 5% late for any activity*
  - *request that the **route planner** be run for those travelers*
- *for iterations 4, 6, 8, 11, 13, 15, 18, 20, 22 . . .*
  - *request that the **traffic microsimulator** be run*
- *for iteration 23 . . .*
  - *request that the **emissions estimator** be run*

Example Study: Iteration Database Fields

- ***Household ID***
- ***Traveler ID***
- *Age*
- *Gender*
- *Income*
- *Working Status*
- *Trip ID*
- *Beginning Activity Type*
- *Beginning Activity Location*
- ***Ending Activity Type***
- *Ending Activity Location*
- ***Preferred Arrival Time***
- *Planned Arrival Time*
- ***Simulated Arrival Time***

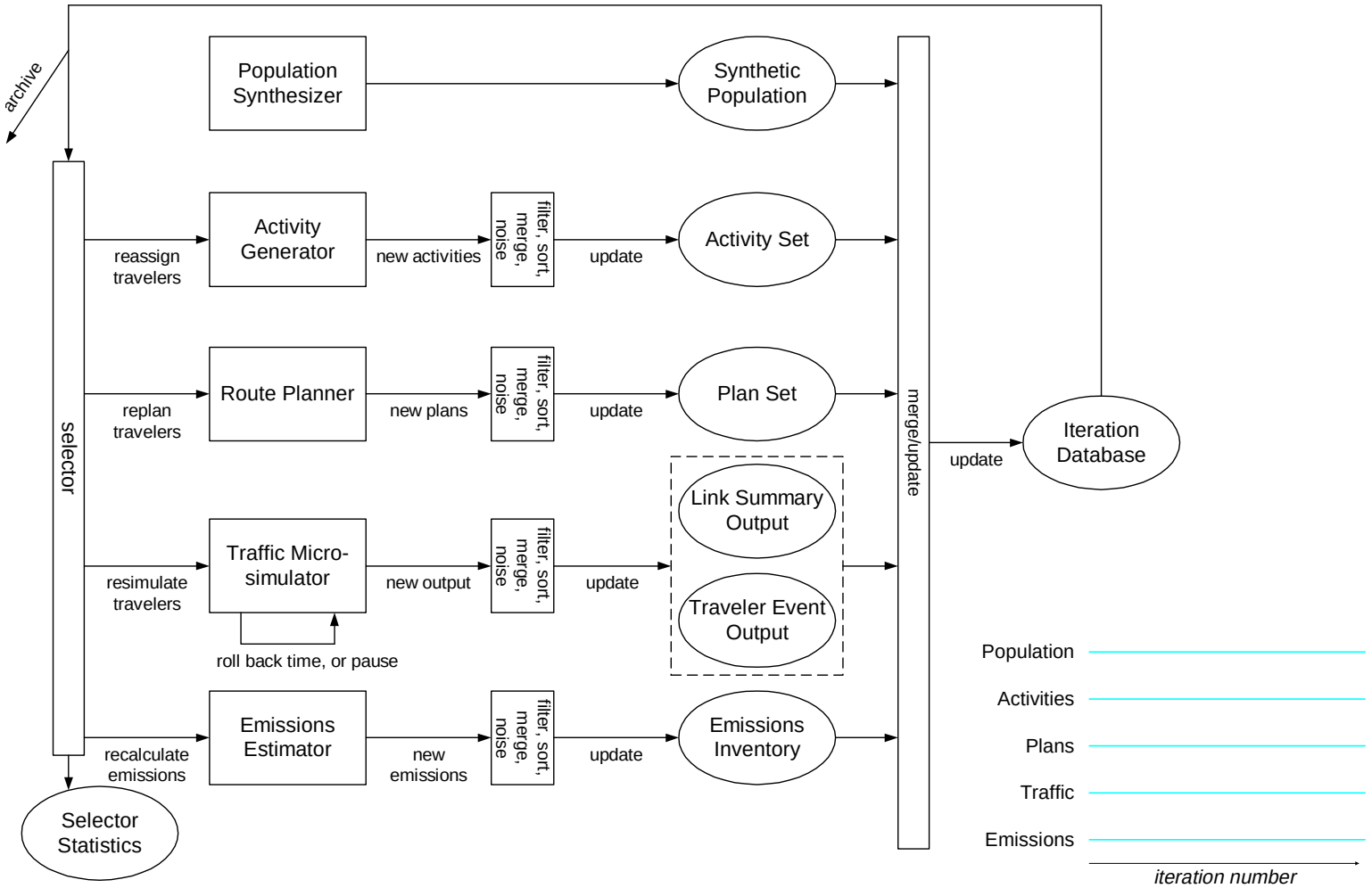
Example Study: Iteration Script

```
for iteration := 1 to 23 do
   choice := Selector example.config sel.log
   if choice = 1 then
      PopulationSynthesizer example.config pop.log
   else if choice = 2 then
      ActivityGenerator example.config act.log
   else if choice = 3 then
      RoutePlanner example.config plan.log
   else if choice = 4 then
      TrafficMicrosimulator example.config sim.log
   else if choice = 5 then
      EmissionsEstimator example.config emis.log
   end if
   ArchiveIteration iteration
end for
```

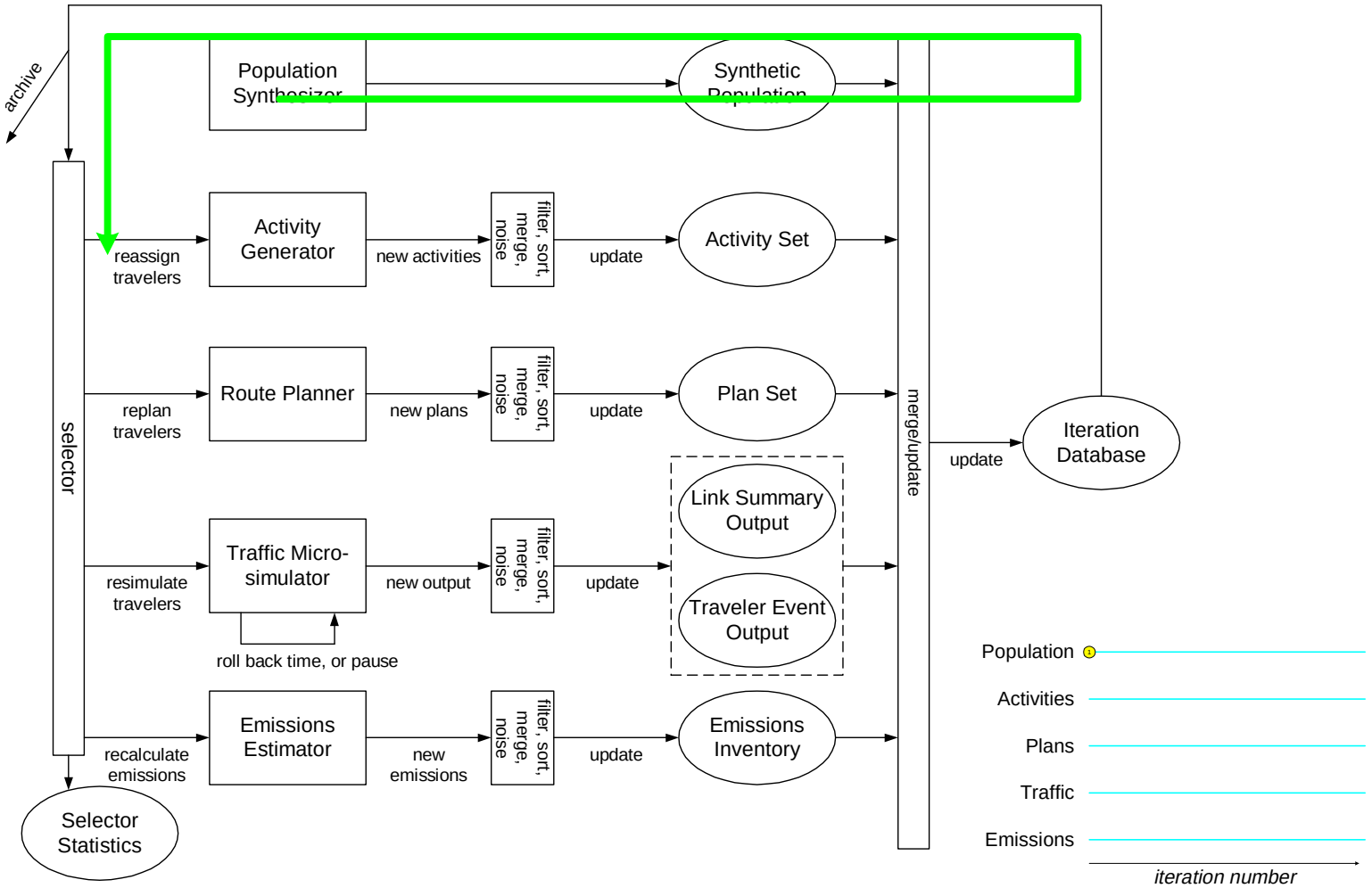
Example Study: Configuration File

```
NET_DIRECTORY           /transims/portland/net
NET_NODE_TABLE          Base_Case_Nodes.tbl
NET_LINK_TABLE          Base_Case_Links.tbl
.
.
.
TRANSIT_SCHEDULE_FILE   /transims/portland/tr-sched.dat
TRANSIT_ROUTE_FILE      /transims/portland/tr-route.dat
.
.
.
CA_MAX_SPEED            4.5
CA_MAX_ACCELER          0.4
CA_DECEL_PROB           0.2
CA_RANDOM_SEED          419845
CA_VEHICLE_FILE         /transims/portland/vehicles.dat
PAR_COMMUNICATION       PVM
.
.
.
```

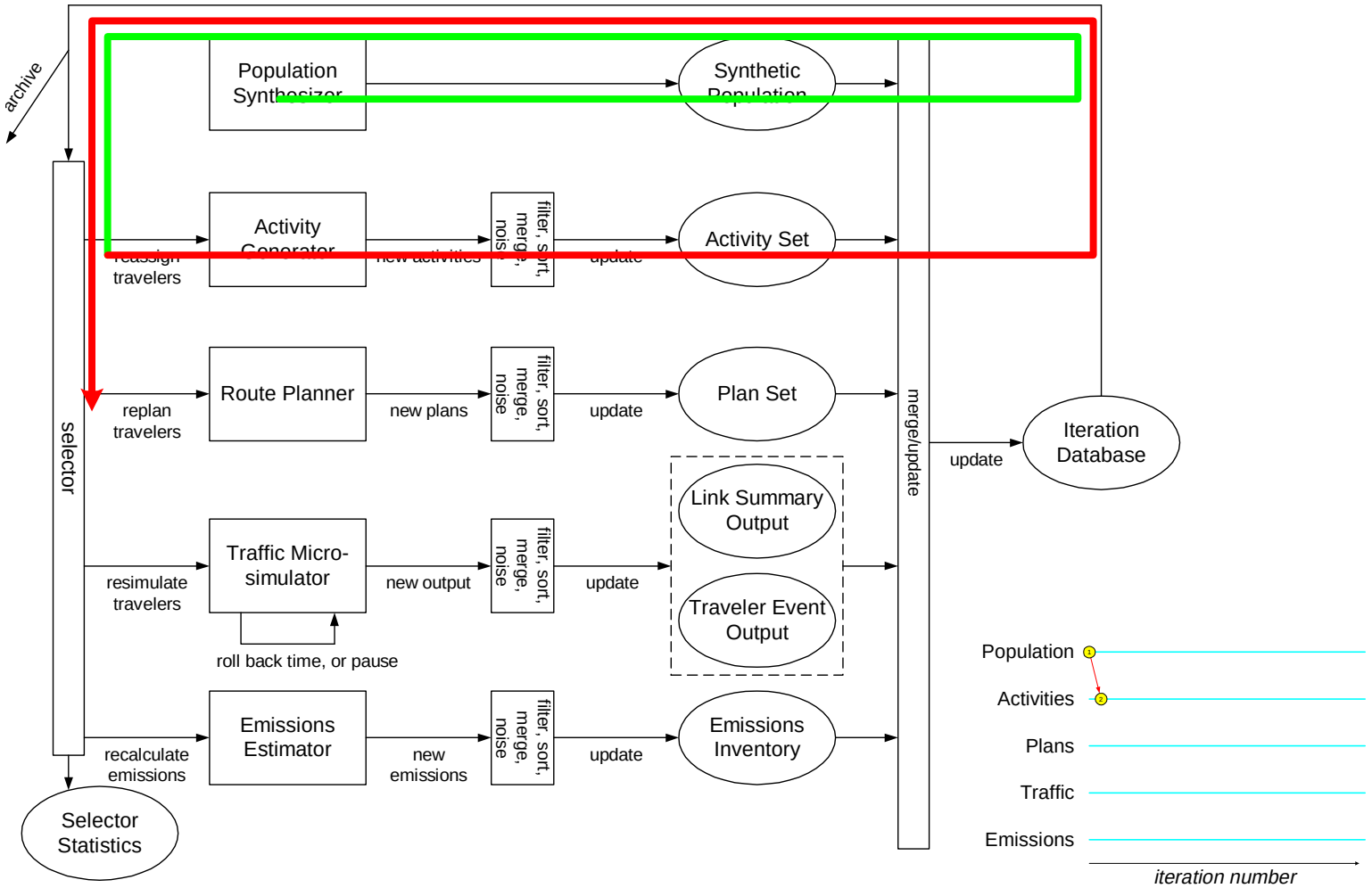
Example Study: Iteration 0



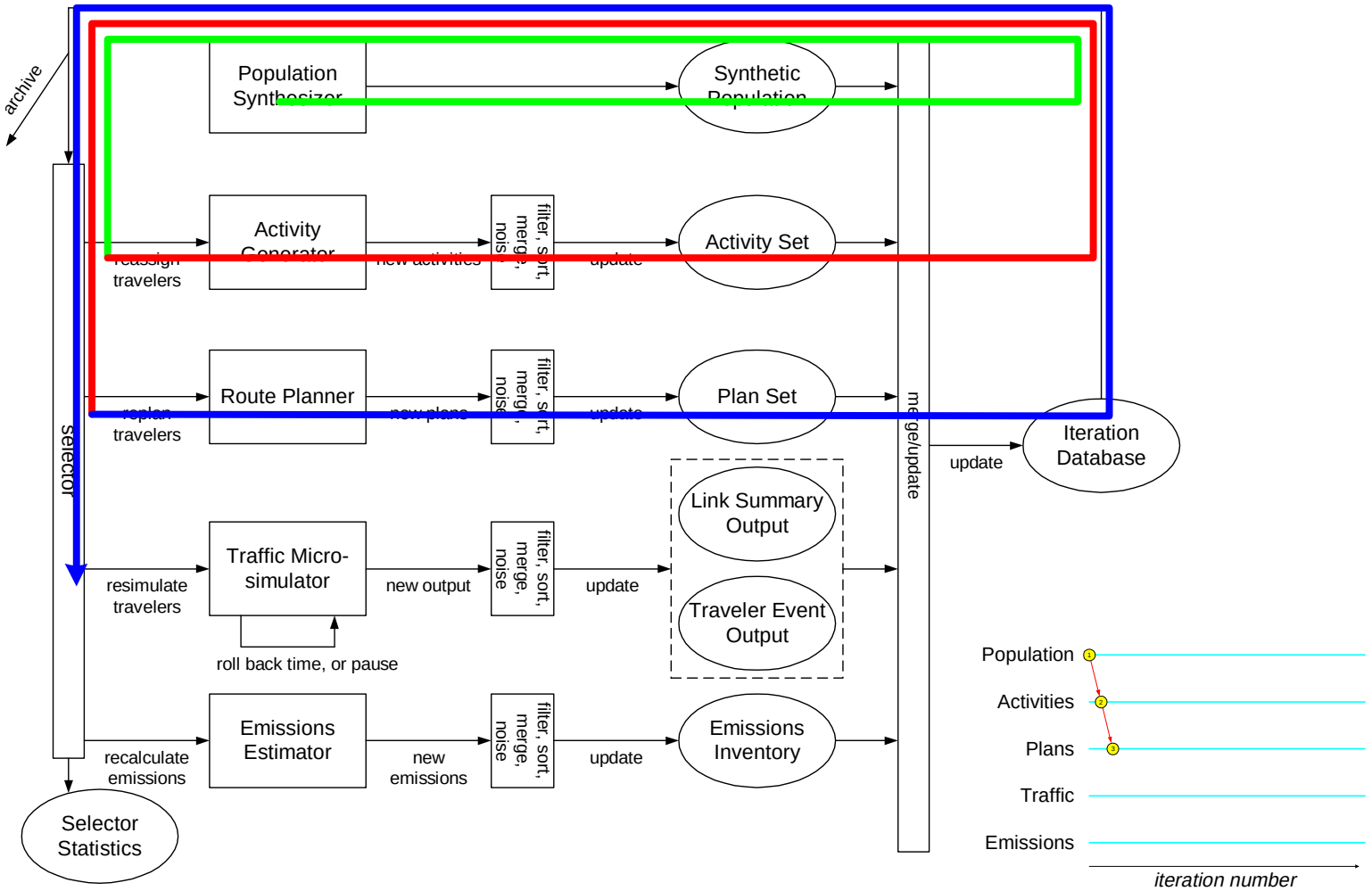
Example Study: Iteration 1



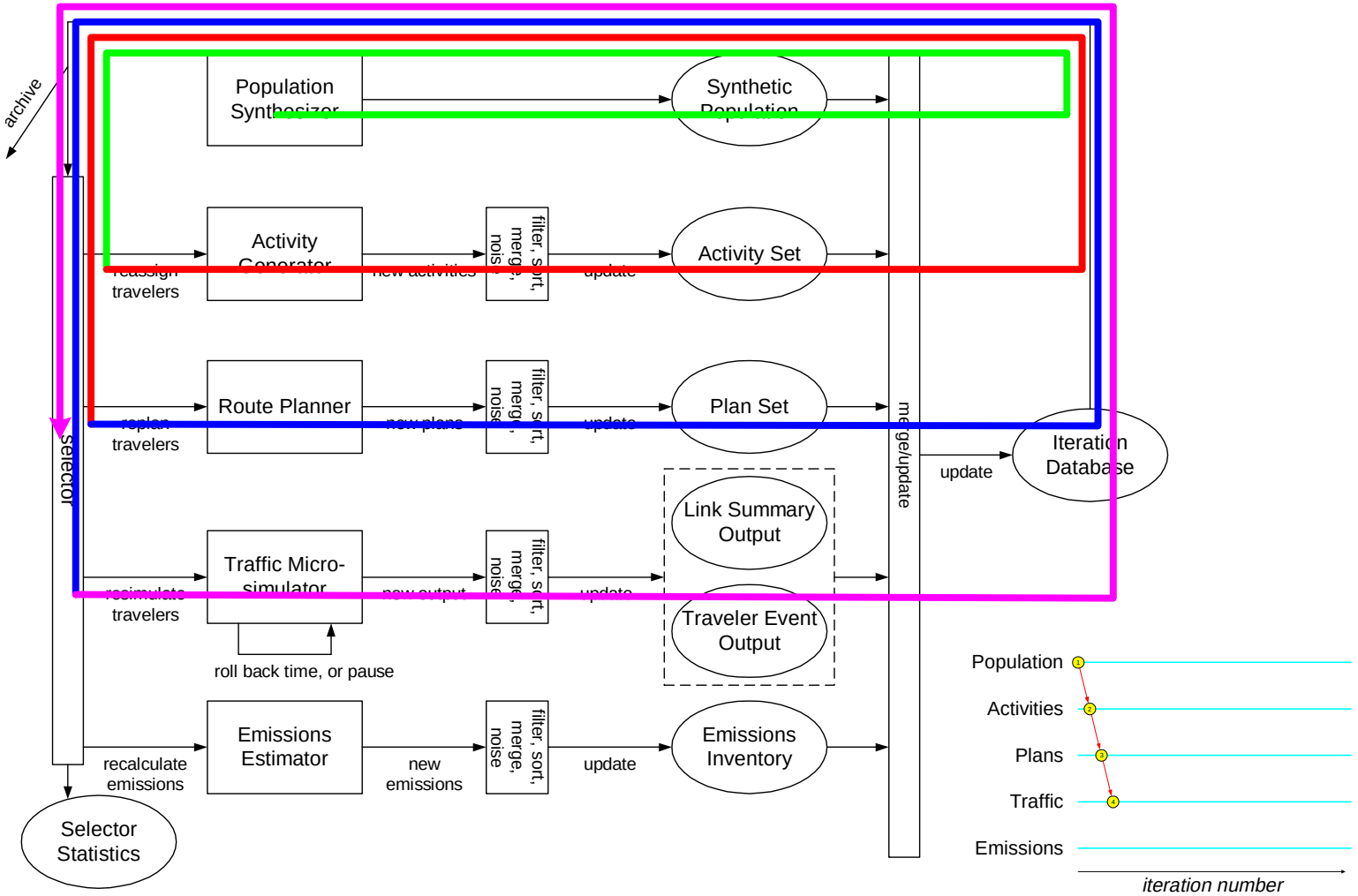
Example Study: Iteration 2



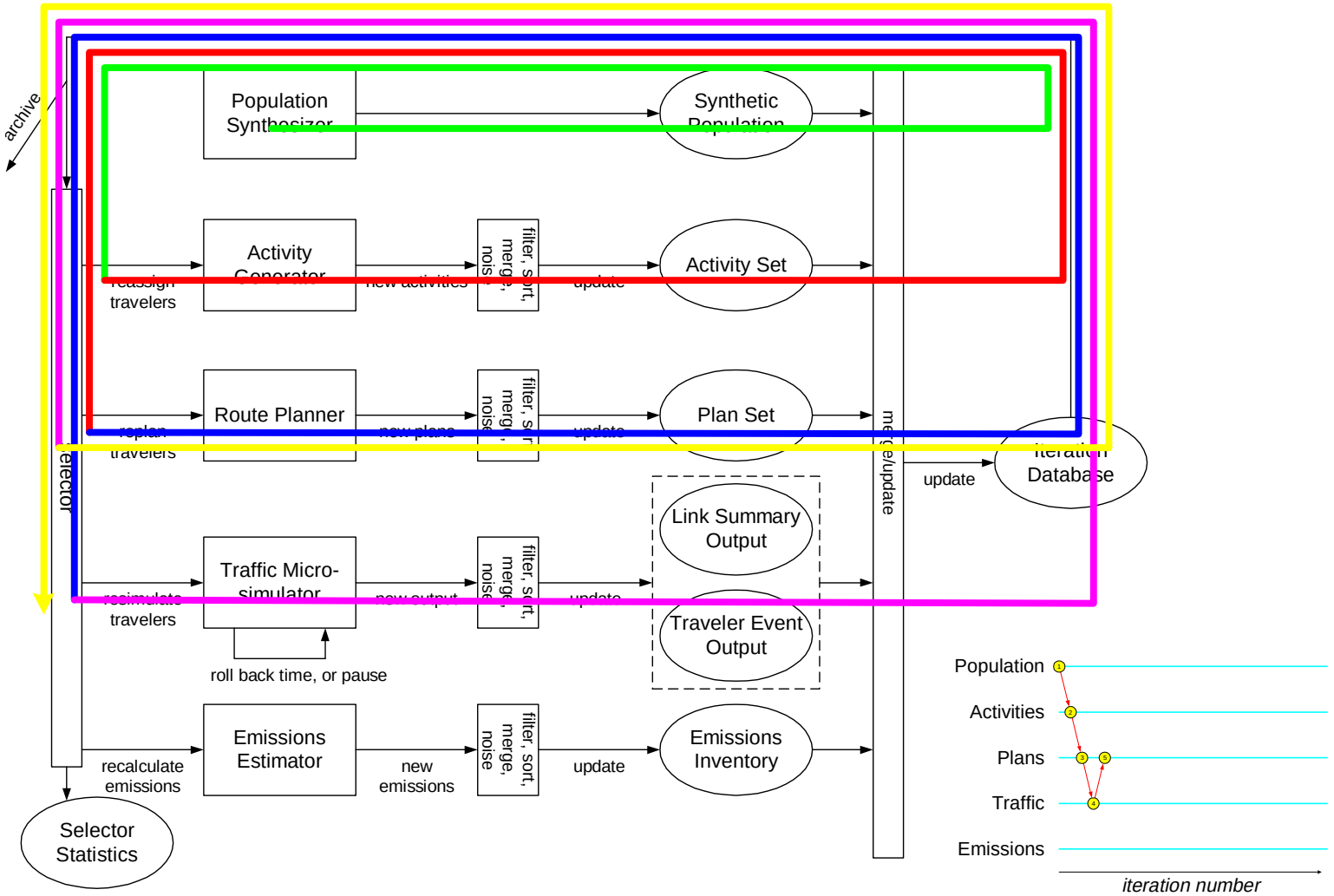
Example Study: Iteration 3



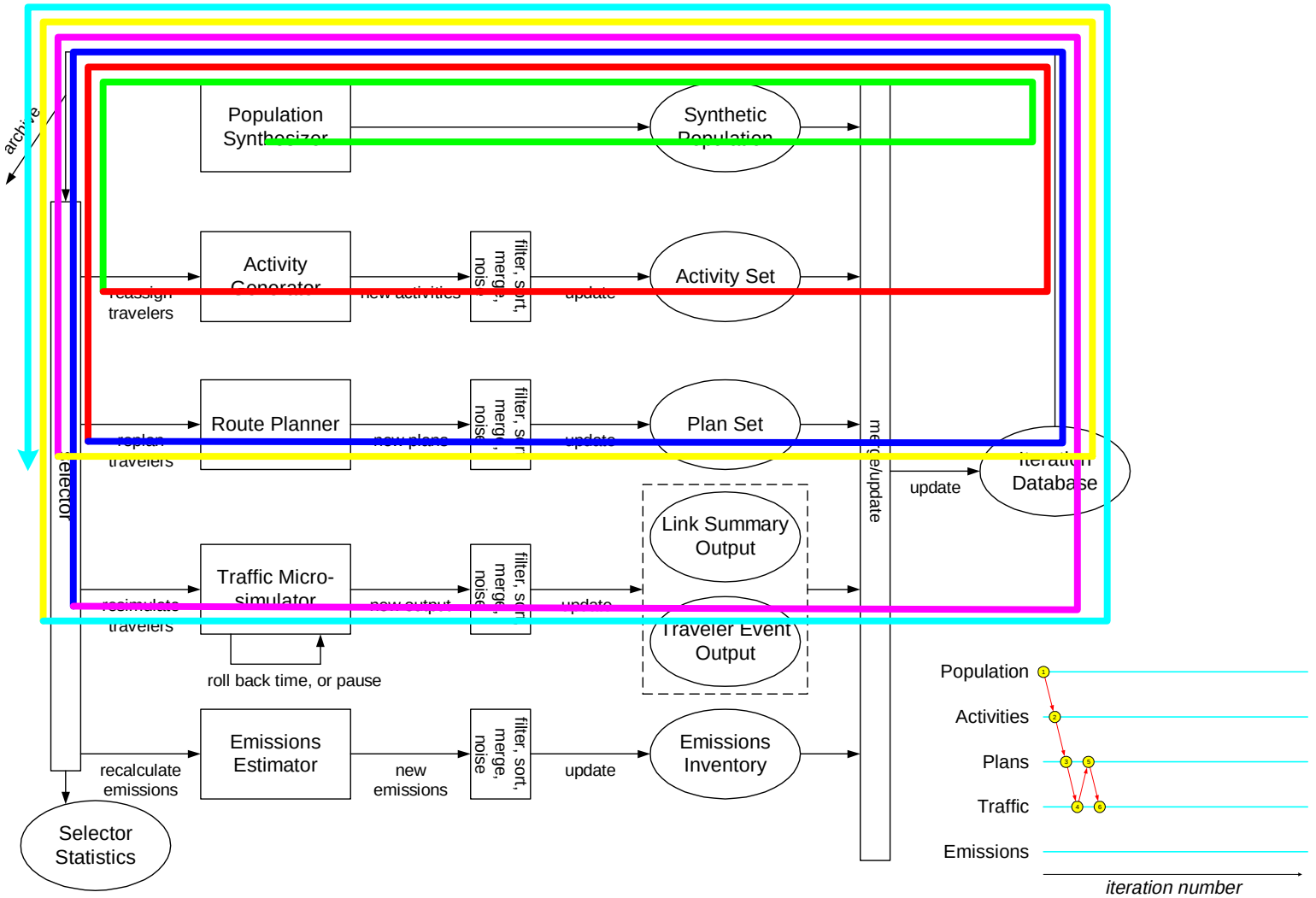
Example Study: Iteration 4



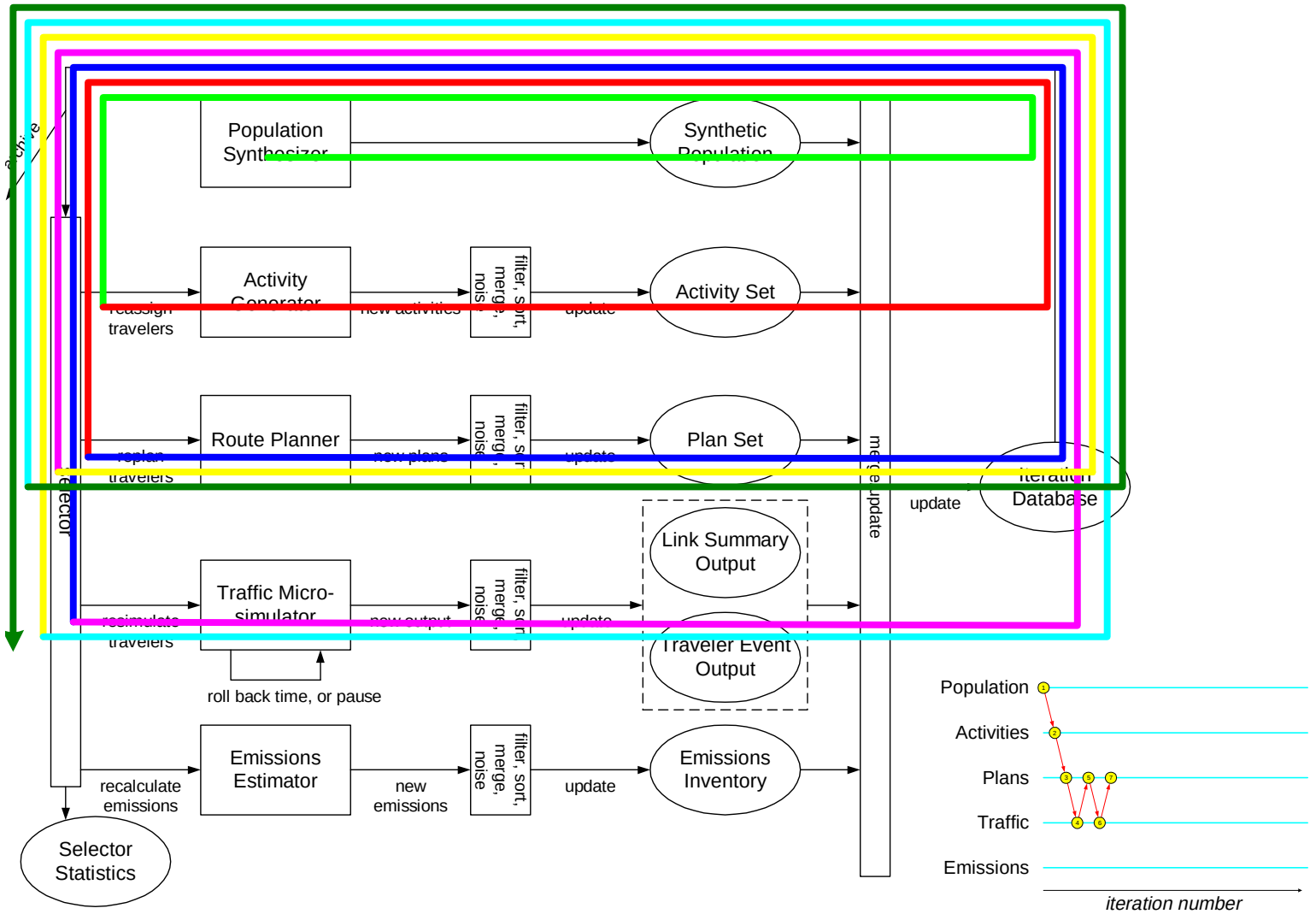
Example Study: Iteration 5



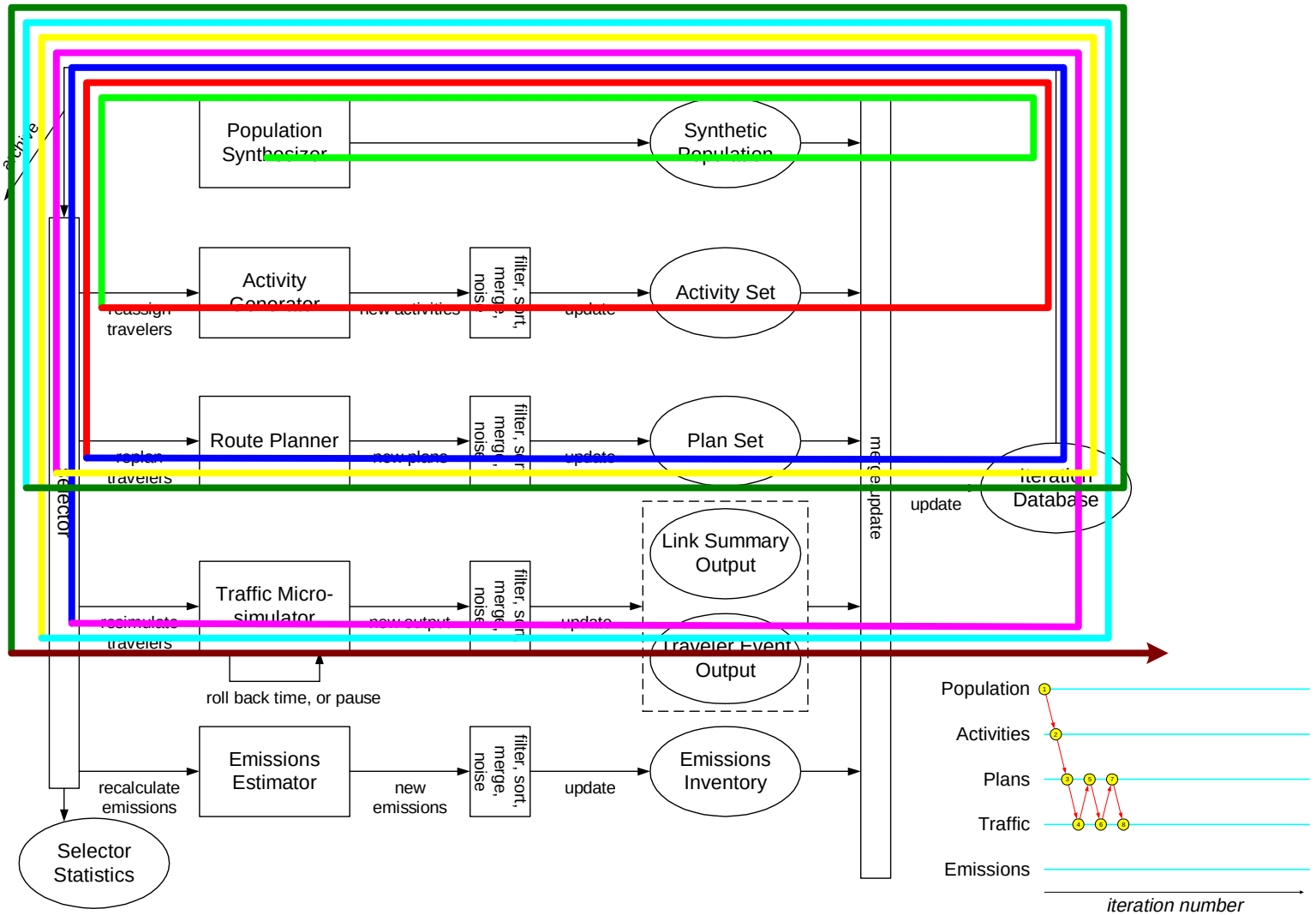
Example Study: Iteration 6



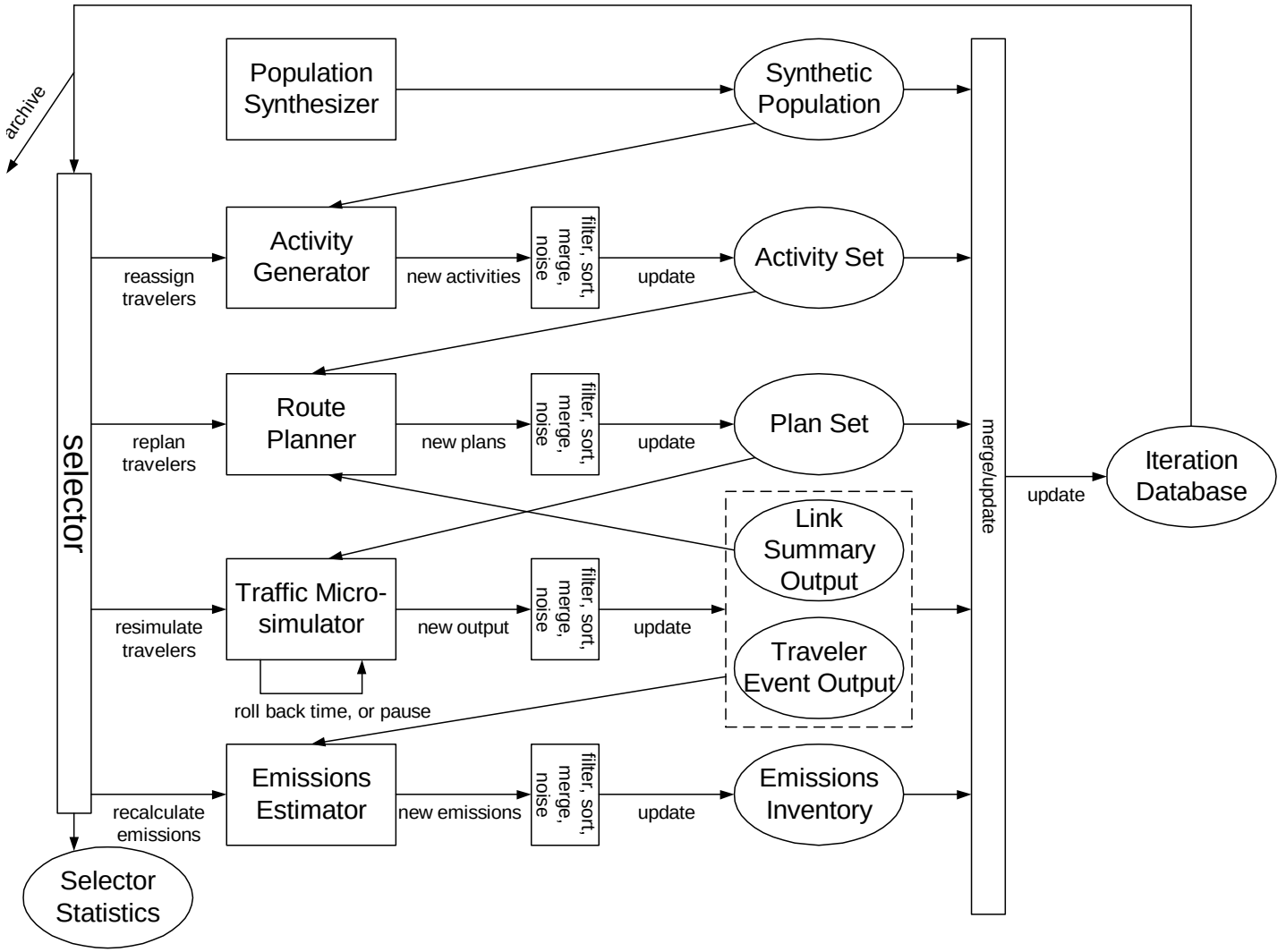
Example Study: Iteration 7



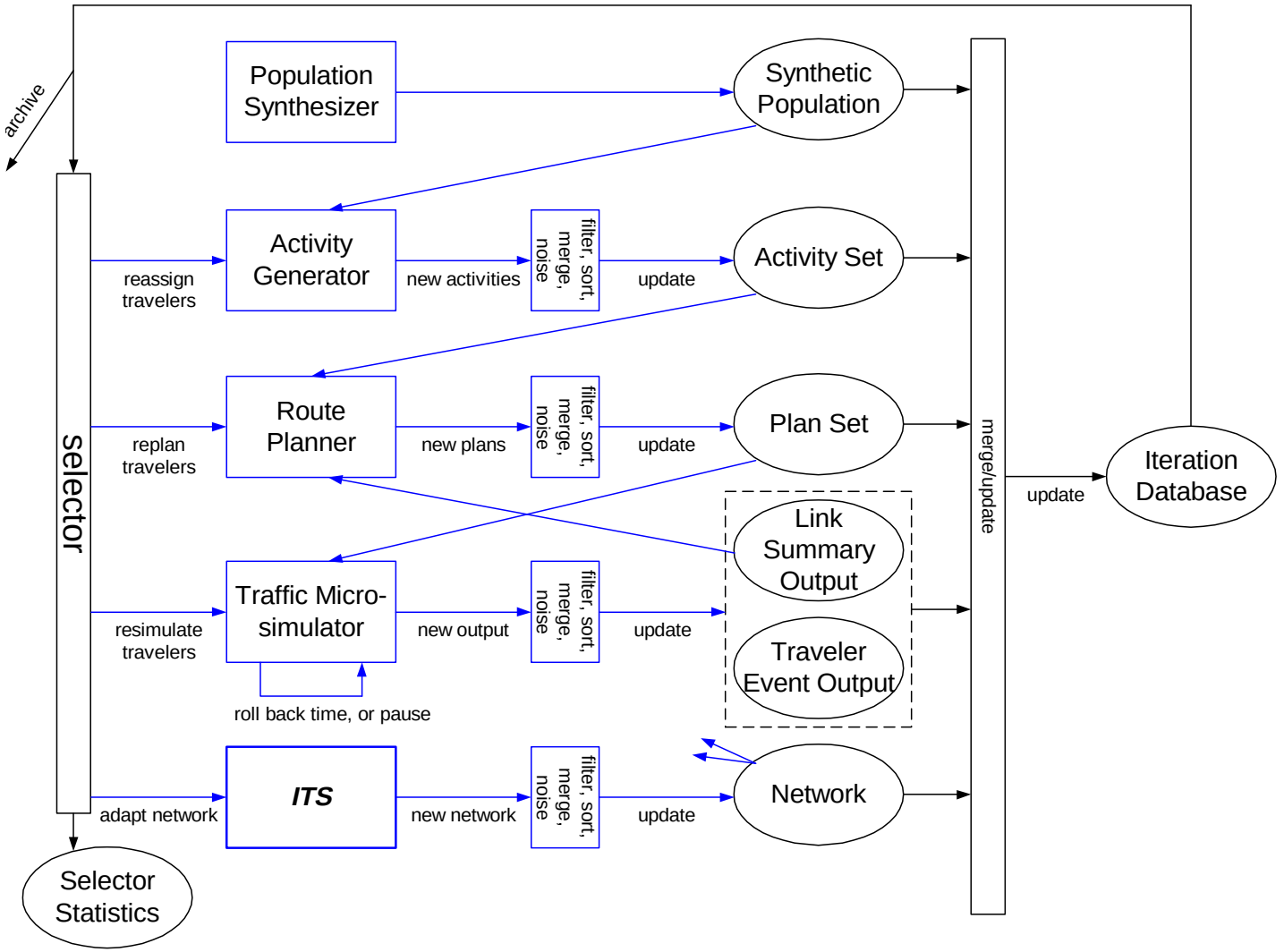
Example Study: Iteration 8



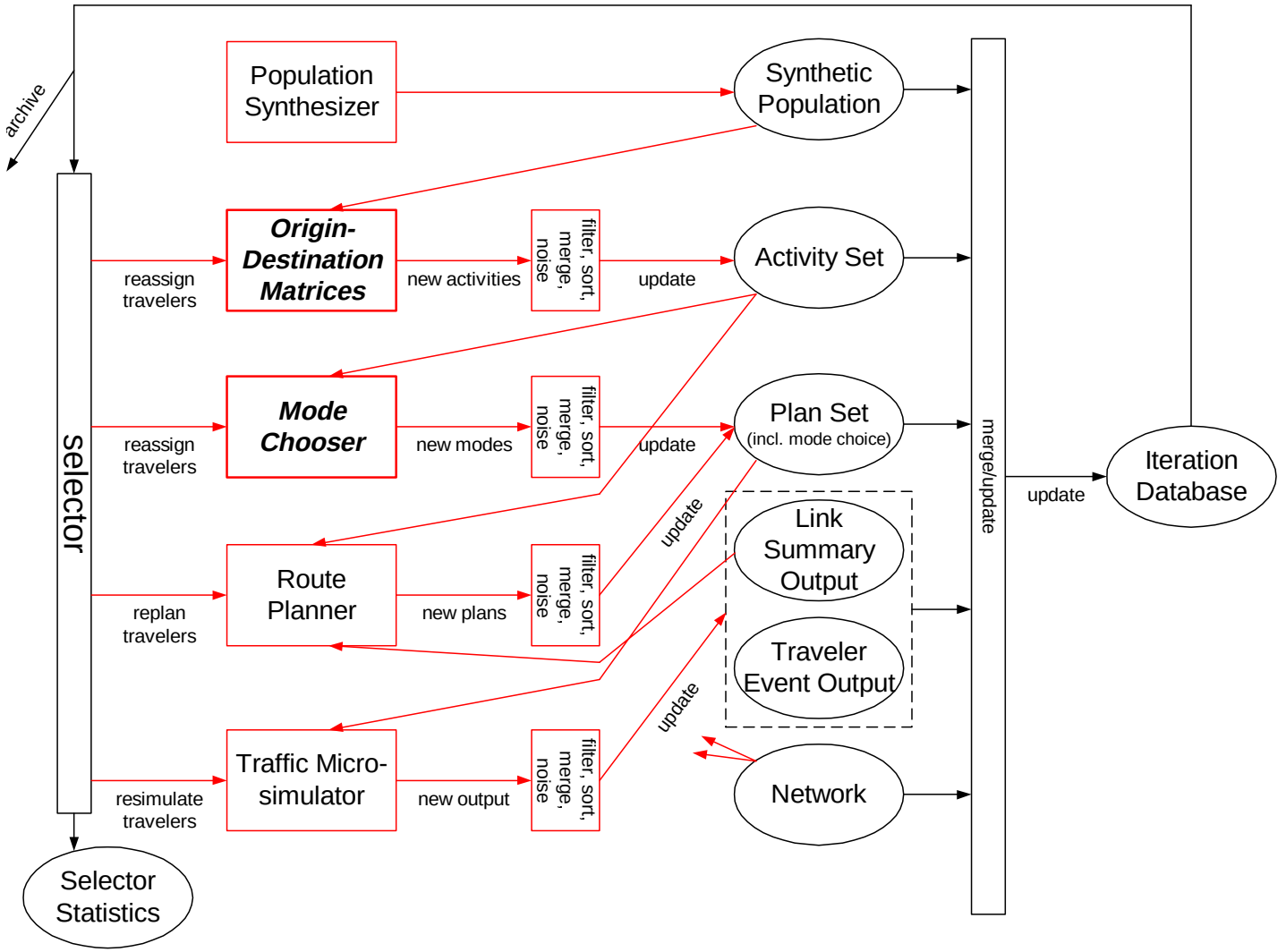
Example #1: Core TRANSIMS Study



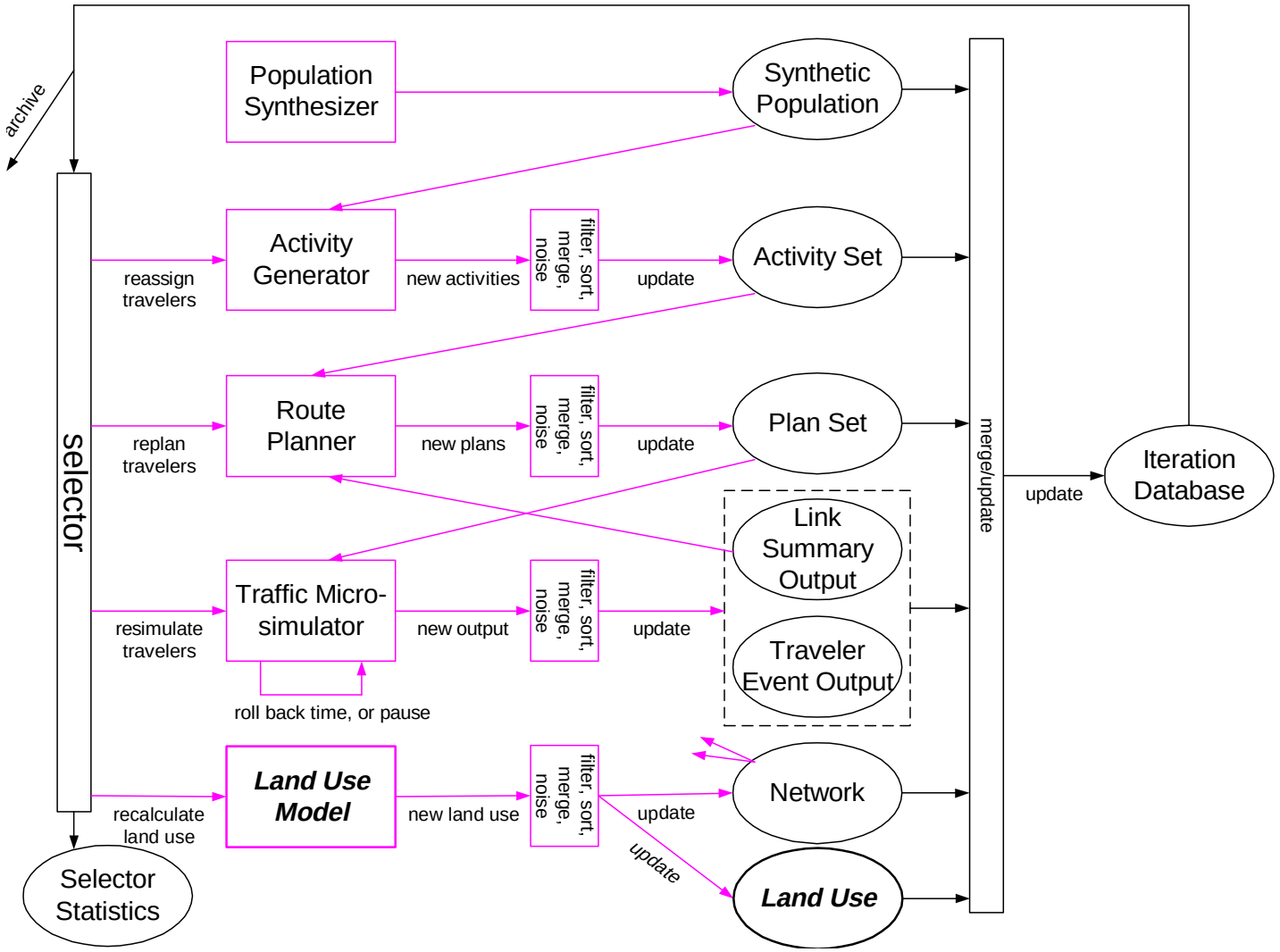
Example #2: Core TRANSIMS with ITS Study



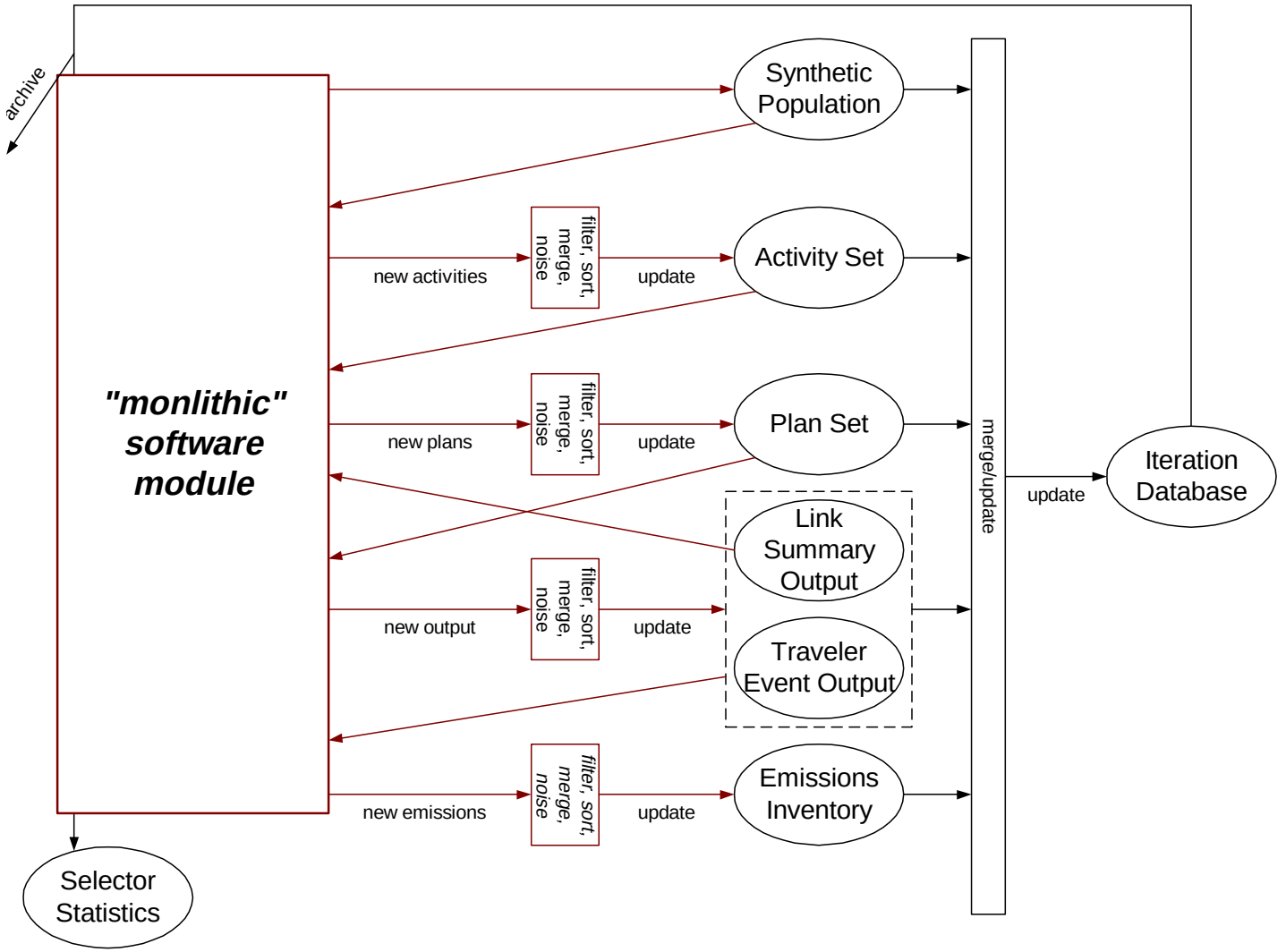
Example #3: IOC-1 Dallas-Ft. Worth Study



Example #4: Land Use Study



Example #5: Study Using "Monolithic" Software



Future Directions

- *Portland regional case study*
  - *base case with validation and analysis*
  - *generic local streets and signalization*
- *ITS enhancements*
  - *rollback of time in microsimulator*
  - *dynamically-changing networks*
  - *more complex data flows and selectors*
    - *emulation of detection devices*
    - *modeling of traveler information systems*
- *more flexibility*
  - *alternate versions of modules with different algorithms*
  - *new types of modules*
  - *new selectors and selector support tools*
  - *new template "iteration scripts" for experiments*
- *optimization of existing software*

Summary

- *flexible software system*
  - *loosely coupled building blocks*
    - *components*
    - *data files*
    - *tools*
    - *selectors*
    - *iteration scripts*
  - *integrated*
  - *customizable*
  - *extensible*

  ⇒ *many possible realizations of TRANSIMS*
- *to meet research community and MPO needs*